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BOOK

(UNCL) ELEMENTS OF PLANNING MACHINE WORKS

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CHAPTER III

Designing of Mechanical Shops10. Classification of Mechanical Shops and their Composition

The classification of mechanical shops is based on the following indications (Table 2):

- (1) Character of construction and weight of products, determination of the subdivision of shops into four classes;
- (2) Type (form) of production and character of technological process, equipment and appliances fundamental for subdividing the shops of each class into groups;
- (3) Dimensions of shop, characterized by the tentative number of metal-cutting machines.

Class I relates to shops making products of light machine-construction, with a weight (rough) of the treated parts up to 100 kg (the names of these products are listed in Table 2).

Class II relates to shops making products of medium machine-construction, with a weight (rough) of the treated parts up to 2000 kg.

Class III relates to shops making products of heavy machine-construction, with a weight (rough) of the treated parts up to 15,000 kg.

Class IV relates to shops making products with a weight (rough) of the treated parts above 15,000 kg.

Besides the indications serving as the basis for assigning the shops of each class to one or another group, each of the groups of shops is characterized by the particularities of the individual factors of the production - packing, differentiated into operations, differentiated into elementary operations; equipment - general purpose, specialized, special; appliances - universal, special; cutting tools - general purpose, standard, special super-special; measuring implements - general purpose, universal, calipers, gages.

Table 2

Classification of mechanical shops

I			
class			
group	1	2	3
type of production	unit and small-series	series	large-series and mass
character of products	of light machine-construction		
products	fine metal-cutting machines for watch and instrument production and apparatus construction apparatuses. Fittings. Standard measuring implements and cutting tools. Antifriction bearings Special apparatuses. Special cutting tools and measuring implements. Stamps. Equipment and accessories for machines		
weight (rough) of treated parts in kg	up to 100		
dimensions of mechanical shop according to number of metal-cutting machines	(a) small to 150 (b) medium 150-300 (c) large more than 300		
characterization (a) technological process	Concentrated. Largest possible number of operations carried out on one machine	Differentiated into operations carried out on particular machines	Differentiated into elementary operations or concentration of operations on automatic or aggregated machines
(b) equipment	general purpose	general purpose; specialized; special; automatic	general purpose; specialized; special; automatic; aggregated machines

(c) appli- ances	universal	universal and special	special and universal
(d) cutting tools	general purpose, standard	special and standard	narrowly-special and standard
(e) measur- ing imple- ments	general purpose, universal	calipers and gauges	calipers and gauges, special
class	II		
group	1	2	
type of pro- duction	series	large-series and mass	
Character of products	products of medium machine-construction		
	metal-cutting and woodworking machines. Textile and shoe machines. Motors, Diesels, compressors and pumps of small and medium power. Nar- row-gauge locomotive of small and medium power	Automobiles, tractors. Engines for automobiles, tractors and the like. Motorcycles, bicycles. Agricultural machines. Electric motors of small and medium power	
weight (rough) of treated part in kg	up to 2000		
dimensions of mechani- cal shop according to number of metal-cut- ting mach- ines	(a) small to 125 (b) medium 125-250 (c) large more than 250		
characteri- zation (a) technologic- al process	differentiated into opera- tions carried out on partic- ular machines	differentiation into elementary operations of concentration of opera- tions on automatic or aggregated machines	
(b) equip- ment	general purpose; specialized; automatic machines	specialized; special; automatic machines; aggregated machines	
(c) appli- ances	universal and special	special and universal	
(d) cutting tools	special and standard	narrowly-special and standard	

(e) measuring implements	calipers and gauges	calipers and gauges, special	
class	III		
group	1	2	3
type of production	unit and small-series	series	large-series
character of products	Heavy metal-cutting and woodworking machines of large dimensions. Forge hammers and presses. Motors. Diesels, pumps and compressors of large power. Water and steam pipes. Steam engines. Mining and metallurgical equipment. Polygraphic machines of large dimensions. Electric motors of large power. Lifting-transporting equipment of heavy types. Road machinery.		
weight (rough) of treated parts in kg	up to 15,000		
dimensions of mechanical shop according to number of metal-cutting machines	(a) small to 100 (b) medium 100-200 (c) large more than 200		
characterization (a) technological process	concentrated; largest possible number of operations carried out on one machine	differentiation into operations carried out on particular machines	differentiation into elementary operations of concentration of operations on automatic and aggregated machines
(b) equipment	general purpose	general purpose; specialized	specialized; special; automatics; aggregates; <u>general purpose</u>
(c) appliances	universal	universal and <u>special</u>	special and universal
(d) cutting tools	general purpose, <u>standard</u>	special and standard	universal and standard
(e) measuring implements	general purpose, universal	calipers and gauges	calipers and gauges, special

1	class	IV
3	group	1
5	type of production	unit and small-series series
7	character of products	products of particularly-heavy machine-construction
9		Rollingmill and blastfurnace equipment. Particularly-heavy metal-cutting machines. Hydraulic presses, powerful motors and turbogenerators. Water pipes. Car dumpers
11	weight (rough) of treated parts in kg	above 15,000
13	dimensions of mechanical shop according to number of metal-cutting machines	(a) small to 75 (b) medium 75-150 (c) large more than 150
15	characterization (a) technological process	concentrated; largest-possible number of operations carried out on machine
17	(b) equipment	general purpose
19	(c) appliances	universal
21	(d) cutting tools	general purpose, universal
23	(e) measuring implements	general purpose, universal
25		different into operations carried out on particular machines
27		general purpose; specialized; special
29		universal and special
31		special and standard
33		calipers and gauges
35	11. Basic data for planning mechanical shops	
37	Into the composition of a mechanical shop there enter:	
39	(1) The production departments and sections;	
41	(2) The auxiliary departments;	

- (3) Office space;
- (4) Living quarters;
- (5) Rooms for social organization.

The composition of the production departments and sections of the shop is determined by the character of the products made, the technological processes, and the volume and organization of the production.

The production departments and sections serve for placement of the equipment and as working places for carrying out the technological processes of the treatment of parts, and, in some cases, for assembly.

The auxiliary departments of the shop relate to:

Functions of an auxiliary character (readying, sharpening, repairing, etc);

Control department;

Storerooms for materials, blanks, parts, auxiliary materials.

The office space includes rooms for the technical parts of the shop, administrative-technical personnel.

The living quarters house lockers, washrooms, toilets, recreation rooms, medical facilities for first aid, cafeterias, smoking rooms.

Important in the planning of mechanical shops are the production program of the works with accompanying diagrams, specifications of the parts, descriptions of the designs and technical conditions on the processing of the products.

The production program (task) for the planning of machine-building works, used as basis in carrying out the planning, must in general contain:

- (1) Nomenclature of the products made, with indication of their dimensions, types, and marks;
- (2) Number of pieces of each kind and type-dimensions to be turned out per annum;
- (3) Weight of one piece, and total weight of their yearly number;
- (4) Estimated cost of one piece and total cost of output per annum;

(5) List and quantities of supply parts for products made, their weight and cost.

All of these data are prepared in the form of special documents.

The drawings must include:

- (1) Working drawings of the elements of the products made;
- (2) Assembly drawings of the parts and products;
- (3) Drawings of the general form of the products;
- (4) Specifications on parts of each product;
- (5) Descriptions of designs; and, if possible, pictures (photographs) of the products;

(6) Technical conditions on the processing and delivery of the products.

The working drawings, necessary for formulating the technological processes of the treatment of the parts on metal-cutting machines, must indicate the following:

- (a) The form of the blank;
- (b) The material and its mark;
- (c) The surface to be treated;
- (d) The required cleanness of the surface after treatment;
- (e) The permissible inaccuracy of the treatment;
- (f) The form of the thermal treatment.

The drawings of the assembly and general form must indicate:

- (a) The clearance between parts;
- (b) The dimensional tolerances, determined by the relative position of the parts;

(c) The special requirements on the assembly of the connections or the mounting of the whole machine.

The specifications on the parts of each of the products must indicate:

- (a) The name of the part (including the tradename);
- (b) The weight of the part - finished and rough;
- (c) The material - its mark, chemical composition, and mechanical characteristics;

- (d) The character of the blank;
- (e) The number of elements necessary for one piece;
- (f) The standardized part (according to GOST or OST).

The description of the design of the products is necessary for a correct and complete understanding of their operation, the significance and function of the individual parts and their interworking.

The technical specifications as to the processing and delivery of the products are determined by the requirements to be satisfied by the product (machine) as a whole and with respect to its elements; the methods of their processing are selected accordingly.

12. Fundamental Problems to be Solved in the Planning of Mechanical Shops

In the planning of a mechanical shop, the following fundamental questions must be solved in sequence:

1. Formulation of the function of the planned shop, starting with the production program of the works, the drawings, descriptions of the designs and the technical specifications for manufacturing the products.
2. Selection of the form of the blanks (which is carried out when planning the technological processes); determination of the yearly requirements of starting materials, blanks and semifinished products, and also of auxiliary materials. Formulation of these data for the planning of the foundry and forging shops and for organization of the service of material-technical supply of the works.
3. Planning of the technological production processes for the various elements of the products and formulation of the organized form of the execution of these processes (establishment of the forms of the organization for actual

operations).

4. Determination of the required number of machines for performing the tasks of the production program and determination of their loads.
 5. Selection of the types of the equipment, compilation of the specifications of the equipment, appliances and tools, compilation of the characteristics of each of the machines, ascertainment of the capacity of the selected machines.
 6. Determination of the total demands of the shop for electroenergy, gas, steam, compressed air, water.
 7. Determination of the required working staff.
 8. Selection of the types and determination of the required number of shop transports and load-lifting apparatus.
 9. Preparation of the plan of the location of the equipment in the shop.
 10. Determination of the pieces of equipment and the areas of the auxiliary departments (shop stores, control department, etc.), and also of the areas of the service rooms (controls, lockers, lavatories, toilets, etc.).
 11. Determination of the principal dimensions of shop building, and selection of its type.
 12. Composition of the whole shop, determination of the area required for the whole shop, adaptation of the plan of the shop to the general plan.
 13. Formulation of the scheme of the organization of the administrative and technical management of the shop.
 14. Formulation of the economic aspects of the plan.
13. Production Program for the Planning of Mechanical Shops

For the planning of mechanical and assembly shops it is necessary in principle to express in general form the production program of the works composed of the individual production programs, showing how the elements must be treated in the given shop. If an element has to be treated in more than one shop, a program (in the form of a bulletin) is composed for each of the shops, in which

Form 1

The detailed list is set up according to Form 1.

A production program is called precise, when the nomenclatures of all of the products and their elements (including the supply parts) are precisely established on the basis of working drawings, specifications and technical conditions.

[illegible]

program requires the detailed formulation of the technological process of production of each of the elements with preparation of the detailed technological chart. This work is exceedingly voluminous, requires much time, a large staff of designers and assistants, and a considerable expenditure of means. Consequently, this method of planning is suitably applied to shops for mass production, where the planning requires high accuracy of the technological calculations. In the planning of shops for small-series and medium-series production, detailed formulation of the technological processes is carried out only for the fundamental, most characteristic and complicated elements and machines. For the other simpler and smaller elements, operational lists are prepared, indicating the general course of the technological processes.

Planning according to a precise program of an individual production is relatively infrequent, since with this form of production it is not always possible to obtain the accurate nomenclature of the products. Even in the presence of an accurate program for this form of production, the formulation of the technological processes for all of the elements is irrational and difficult because of the large number of different elements and the production of single pieces. In this case, all of the elements should be subdivided into groups of elements similar to one another in the character of their processing and close to one another in weight, selecting for each of the groups the most characteristic element, which is "representative" of the given group; it will be sufficient to formulate the technological processes for these representative groups and to extend the obtained data to all of the elements of the corresponding group.

In the planning it is not always possible to have an accurate program, i.e., one with whose help the accurate nomenclature of the products, as well as the technical conditions, the drawings and specifications for all of the elements of these products can be established. In the planning, such complete data are often available only on the principal types of products (machines) and, on the rest,

only general, not-detailed information. It may also occur that the production program includes a large nomenclature of products, and it is not possible (and sometimes not desirable in view of similarity of designs) to formulate the technological processes for all of the elements of all of the products. In this case the planning is done according to types of machines, constituting the so-called allocation program.

The production program is called allocation when all of the products to be produced are tentatively allocated to particular types of machines which are the most characteristic of each of the groups of machines.

As follows from the foregoing, planning according to an allocation program, in an extensive and diverse nomenclature of the products to be produced, and also in the presence of complete data (drawings, specifications, technical conditions) is employed only on the basis of typical products of the program and general information of all the rest.

The allocation program serves principally for the planning of shops of small and medium-series as well as of unit production.

For the construction of an allocation program for a given shop the list of products is divided into groups which usually contain products which are the most similar to each other in design and technology, in which each of the groups is represented by one typical machine which is characteristic of the given group and the rated representative of all of the machines of the given group. For the determination of the capacity of each of the machines there is used, the coefficient of allocation, determined by the ratio between the capacity of the rated machine and that of each of the machines of the given group.

In the determination of the coefficient of allocation the differences in weight, seriality and complexity of the machines, expressed by the individual coefficients (k_v , k_{ser} , k_{g1}), are taken into consideration and used as basis for deriving a generally applicable common coefficient of allocation. The common coefficient of

allocation is

$$k_0 = k_v \cdot k_{ser} \cdot k_{sl}$$

An exemplary form of allocation program is shown in Table 3.

The planning of mechanical shops according to the allocation program may be carried out in the following variants:

1. When it is necessary to obtain a great precision for each of the calculated machines the technological processes (in the form of a chart of treatments) are formulated on the fundamental, characteristic and complicated elements, and, on the others, the list of operations which are common to the course of the technological process. The results of the detailed formulation are extended to all of the machines entering into the given group with the help of the coefficients of allocation (Table 3).

2. A further simplification may be obtained by dividing all of the elements of the calculated machine into groups of elements coming close to each other in the character of their treatment and in their weight. From each such group there is selected the most characteristic representative element. The technological process for the representative element is extended to all of the remaining elements of the corresponding group.

3. With a long and diversified list of machines included in the production program, results sufficiently precise for practical purposes can be obtained in the following manner. All of the details of all of the machines are divided into groups according to indices of constructional, dimensional (gravimetric) and technological similarity (group of plates, frames, bases, group of axles and shafts, groups of pulleys, flywheels, couplings, etc.).

In each of the groups there is selected one or two representative elements, for which there are formulated the technological processes, which are extended to all of the details of the given group.

In planning according to an allocation program of an individual production

Table 3

Given and Allocation Programs of Production of Products							
Given Program			Allocation Program				
Name of Product	Type or Mark	Technical Characterization	Number Produced per Annum	Weight of Product Processed in Shop One Total	Name of Product Representative	Coefficient of Allocation (given) by Weight k_w by Seriality k_{ser} by Complexity k_{cl} General k_g	Yearly Output of Products in Conditional Units
Sheet-bending rolling mill	Three-roll	32 — 42 × 2500	10	48.5 485.0	Sheet-bending rolling mill 32 — 42 × 2500	1.0 1.0 1.0	10.0
"	"	"	"	"	"	"	"
"	Four-roll	11 — 18 × 4000	5	29.0 145.0	"	0.71 1.0 1.3	4.6
"	"	"	"	"	"	"	"
"	"	20 — 30 × 2500	10	29.0 290.0	"	0.71 1.0 1.3	9.2
"	"	"	"	"	"	"	"
"	"	20 — 30 × 4000	5	39.0 195.0	"	0.86 1.0 1.3	5.6
"	"	"	"	"	"	"	"
Sheet-bending and straightening rolling mill	"	"	"	"	Sheet-bending and straightening rolling mill	"	"
"	"	"	"	"	"	"	"
"	"	10 — 18 × 2000	15	17.5 262.5	"	0.505 1.0 2.0	15.1
"	"	"	"	"	"	"	"
"	"	11 — 16 × 3250	10	24.2 242.0	"	0.63 1.0 2.0	12.6
Total			55	1619.5			57.1

it is necessary to apply a still greater generalization; here all of the elements of the representative of the group of machines are also divided into groups of elements coming close to each other in treatment and weight; on the representatives of these groups there are formulated, not technological charts, as in the preceding case, but only the lists of operations determining the general course of the technological process, with indication of the equipments, tools and total expenditure of time on the operations; the obtained results are extended to all of the elements of the given group.

At the planning of an individual production with a long list of operations it is irrational to formulate the technological processes; in this case it is sufficient to describe its fundamental principles.

In planning according to a tentative program there is also selected a representative - a tentative machine, for which all of the technological planning is carried out, and, without employment of coefficients of allocation, all of the calculations are extended to all of the machines included in the yearly program.

11. Characteristics of Technological Processes and Technical Organization of Unit (Individual), Series and Mass Production

The whole diversified production is divided into three fundamental forms (or types): unit (individual), series and mass. Each of these forms of technological processes has its characteristic particularities, and each of their characteristics a corresponding form of organization of the work in the shop.

Series production occupies in its character a middle place between unit and mass production.

It should be noted that in one and the same enterprise, or even in one and the same shop, there may exist various forms of production, that is, the individual products or elements may be processes in the works or shop according to different principles: the one in units and the other in series, or the masses and the other in series, etc. Thus, for example, in heavy machine-building,

0 having the character of individual production, it is necessary to be able to process
2 large numbers of small elements according to the principle of series or even of mass
4 production.

6 Accordingly, the characterization of the production of the works as a whole is
8 only possible according to the indices of the predominant form of the production
10 processes.

12 The unit (individual) production is universal, and includes diverse types of
14 products, so that it must be very flexible; it must be capable of performing diverse
16 tasks. Therefore, the works must have at its disposal a set of equipment capable of
18 processing a comparatively long list of products. This set of equipment must be
20 selected in such a way that, on the one hand, it is possible to employ various forms
22 of treatment, and, on the other hand, that the numerical ratio between the individual
24 units of equipment guarantee the determined output capacity of the works.

26 The technological process of the treatment of elements in this form of produc-
28 tion has a concentrated character, that is, such that on one machine there are car-
30 ried out several operations, and frequently all of the operations on elements of
32 different constructions and different materials. Because of the diversity of opera-
34 tions carried on the machines, and the resulting unavoidable readjustment
36 of the machine for each of the operations, the technological times of the machine
38 in the general framework of the time norms are not great.

40 The devices for the processing of the elements on the machines also have a
42 universal character, that is, such that they can be applied to various cases:
44 clamps for fastening the elements, angles, supports, etc. Special devices are not
46 employed at all or only in rare cases, since they add considerable expense to the
48 operations, and their employment is not justified by their advantages.

50 The cutting tools for this form of production must also be universal (cutters,
52 reamers, drills, milling-cutters of standard type), enabling the execution of
54 typical operations of treatment of metals. Because of the diversity of the treat-
56

0 ments of the elements the employment of specialized tools would be quite impracti-
2 cable.

4 The measuring instruments employed in the processing of the elements will also
6 be of standard types, i.e., of a type as to permit the measurement of elements of
8 various dimensions; in this case trammels, inside calipers, micrometers, templates,
10 indicators, and other universal measuring devices are used.

12 The diversity of the processed products, the various numbers in which elements
14 of more or less similar construction enter into the production, the various require-
16 ments which must be satisfied by the machines with respect to the precision of
18 treatment of the elements, the quantities and types of the materials employed, the
20 necessity (due to the diversity of the elements) of carrying out various operations
22 on universal equipment - all of this requires particular conditions for a successful
24 performance of the shops and the entire plant. These conditions are characterized
26 by the necessity of a planning-distributing department with sufficiently qualified
28 personnel, able to make fast change-overs of work in the shops and provide the pro-
30 duction means for carrying out various manufacturing processes. Other requirements
32 are: large supplies of various materials, and sufficient storage space for keeping
34 them; qualified working and technical personnel, with sufficient knowledge of and
36 experience in various branches of machine building.

38 These characteristics of this form of production considerably increase the
40 manufacturing cost for the products. An increase in the demand for the given pro-
42 duction, simultaneous with a decrease in its list and a stabilization of the con-
44 struction of the products, gives the possibility of changing from unit (individual)
46 to series production.

48 Unit (individual) production is used in heavy machine building, in shipyards,
50 in plants making complicated equipment for chemical factories, in reconditioning
52 and tool shops, etc.

54 In series production, depending on the number of products in the series, their
56

character and capacity, the repetition of the series in the course of a year, differentiation is possible between small-series, medium-series and large-series production. Such a division is tentative and relative for various kinds of machine building: at one and same number in the lot, but for machines of various forms. Thus, for example, the production of small oil engines of 5-10 hp in lots of 50 units, must be assigned to medium-series and the production of large oil engines of 500-1000 hp in the same lots of 50 units to large-series, because the dimensions of and labor-expenditure on the details of the latter are considerably greater than those of the former engines.

As orienting magnitudes there may be taken the numbers of machines in the series shown in Table 4.

Table 4
Numbers of Machines in Series

Production Series	Number of Machines in Series		
	large	medium	small
Small-series	2-5	5-25	10-50
Medium-series	5-25	25-150	50-300
Large-series	above 25	above 150	above 300

The technological process at this form of production is differentiated, that is, divided into individual operations with assignment thereof to particular machines, at which a limited number of operations must be carried out on each of the machines. The machine tools for the principal elements of the given form of machine must be specialized to such an extent that it is possible to switch from the production of one series of machines to the production of another differing

0 somewhat from the other in construction, or to switch from one of the machines to
2 another similar to the first. For the remaining parts universal equipment is used.
4 This requires specialized devices for carrying out the individual operations of
6 the processing on one or another machine, drilling jigs intended for the particular
8 element, special cutting tools or accessories for the given operation - of the
10 standard type, facilitating and accelerating its execution, and, finally, special
12 measuring devices - templates and calipers, for verifying the interchangeability
14 of the produced elements. All of these means may be applied rather widely in
16 series production, in view of the fact that, on repetition of the process of treat-
18 ing one and the same element, these means of production result in a technical-
20 economic effect which repays the expenditure involved and still leaves a consider-
22 able gain.

24 In each particular case of selecting a specialized machine, the cost of the
26 expensive accessories or tools must be taken into account and balanced against the
28 expected technical-economic effect.

30 In series production, the workers use lower qualifications than in unit (indi-
32 vidual production, which is a logical consequence of specialization to particular
34 operations and employment of special devices and tools.

36 The economic effect in series production is considerably higher than in indi-
38 vidual production, as a result of lower relative cost of production, better utili-
40 zation of equipment, increased productivity of labor, and also better utilization
42 of the qualifications of the workers. This form of production also comprises:
44 machine-tool building, locomotive and diesel-engine building, production of com-
46 pressors, pumps, fans, textile machinery, woodworking machinery, equipment for the
48 food and lumber industries, for collective agriculture, for the transport indus-
50 try, etc.

52 Mass production is further developed than series production, and is the most
54 widely employed form of production at the present time.
56

Mass production exists in the following forms:

(a) Flow-mass production. In this form of production there is a continuous movement of the products to the working places distributed over the sequence of the technological operations assigned to the particular working places; each of the operations must be executed in approximately the same interval of time, called the beat.

(b) Massstraight-flow production. Here the technological operations are also carried out at particular working places distributed over the sequence of technological operations, but the time for carrying out the individual operations is not always the same (or repeated beats), so that, with some of the machines, the start and stop of the production proceed with interruptions.

Mass production is feasible and economical if a sufficiently large number of products is being manufactured. The general considerations relating to this number may be expressed by the following formula:

$$n \geq \frac{C}{c_c - c_m} \quad (1)$$

where n is the number of production units;

C is the cost of changing from series to mass production;

c_s is the cost per unit product in series production;

c_m is the cost per unit product in mass production.

Among the technical factors determining the feasibility of the adoption of mass production the most important are the scope of the production program and the specialization of the plant in the manufacture of particular types of products, for which the most favorable conditions for mass production consist in a specialization. Such specialization means the production of only one type of product of the same construction. In this case the product must be a standard product. However, the products of mass production in the course of time and with the progress in the art, necessarily are subject to extensive structural modifications

for the purpose of improving their useful qualities or in connection with requirements of a technological character. In such cases it becomes necessary to revise the technological process.

In mass production the technological processes of production and assembly must be formulated and calculated in the most careful manner; the whole process of the production of the elements and of the assembly is differentiated (dis-membered) into elementary operations approximately identical in time (or repeated beat). All of the operations of both production and assembly are carried out on particular machines and working places; each of the machines, each of the working places carries out one particular elementary operation.

Here there are employed special and narrowly-specialized machines, because each of them is intended to carry out one particular operation on the same element. In this connection the devices for the processing must be intended for the particular operations, that is, must be narrowly specialized, adapted for carrying out only the given operation. Very often such devices are inseparable parts of the machines.

For the purpose of lowering the labor expenditure on products of mass production there is widely employed a concentration of operations carried out on automatic machines, aggregate, multiple-cutting and revolving machines, carrying out simultaneously several operations at a small expenditure of fundamental (technological) time. At the present time such forms of machines are very widely employed in production; they are particularly widely employed in the automobile and tractor industry.

The cutting tools employed for carrying out the particular operations are narrowly specialized or adaptations of standard tools.

As measuring implements for verifying the interchangeability of the elements there are employed limit calipers, as well as measuring apparatuses and devices, automatic measuring arrangements.

0 The technical organization of mass production must be very perfect. As
2 already stated, the technological process must be formulated fully and precisely
4 with respect to both the methods of processing and the calculation of the funda-
6 mental technological times.

8 Particularly important in mass production is the technical control, because
10 inaccurate verification of the produced products, late rejection of unacceptable
12 elements, may lead to retardation and distortion of the whole production process.

14 The organization of supply of the working places with principal and auxil-
16 iary materials, semiproducts, cutting, measuring and auxiliary tools, devices,
18 etc. must be very precise. For uninterrupted working at the working places there
20 are necessary very reliable production workers and a rational plan of the working
22 places.

24 Despite the greater original capital expenditure necessary for the organi-
26 zation of mass production the technical-economic effect in a properly organized
28 enterprise is usually high and considerably greater than at series production.

30 The cost of one and the same form of production at mass production is con-
32 siderably lower, the turnover of the means is greater, the processing of the
34 products is more rapid, the output of the production is greater, the expenditure
36 on transport is smaller than in series production.

38 Besides the technical-economic effect obtained with mass production, the
40 latter also has the advantage that it favors the greatest mechanization of the
42 work, differentiation of the process of production into elementary operations,
44 and the employment of automatic machines which can be incorporated in the pro-
46 duction, to be operated by qualified workers alongside of workers with compara-
48 tively low qualifications. Mass production has been widely adopted in auto-
50 mobile- and tractor building, motor building, agricultural machine building,
52 in enterprises making motorcycles, bicycles, sewing machines, typewriters, add-
54 ing machines, phonographs, etc.

15. Forms of organization of work at various forms of production

Each of the mentioned forms of production (unit, individual, series, mass) requires a corresponding form of organization of the work and a corresponding method of location of the equipments, which is determined by the character of the production process and the characteristics of the particular form of production. There exist the following fundamental forms of organization of the work:

(1) According to type of equipment, or shop, characterized mainly by unit (individual) production; for individual elements it is employed in series production;

(2) Object of group, characterized mainly by series production: for individual elements it is employed in mass production;

(3) Flow-series, or variable-flow, characterized by series production;

(4) Straight-flow, characterized by straight-flow production;

(5) Continuous flow, characterized by flow-mass production.

Each of the mentioned fundamental forms of working has several variants differing from each other in a greater or smaller degree of perfection of the production process.

The form of organization of the work according to type of equipment, or shop, is characterized in that the machines are located according to similarity of treatment, that is, there are created sections of lathing, planing, milling-cutting and hence of similar machines.

The object or group form of organization of the work provides for the location of the machines in the sequence of the technological operations, so that there is created a movement of the elements according to a predetermined plan of sequence of operations. The machines are located in the sequence of the technological operations for one or several elements requiring the same sequence of treatments. The treatment of the elements on the machines occurs in lots; at this the time of operation on individual machines is not the same as the time

0 of operation on other machines. During the working time the elements are kept
2 at the machines, and then transported in whole lots. The elements awaiting
4 transportation to the next machine for carrying out the next operation are de-
6 tained either at the machine or on a special area between machines, on which there
8 is carried out the inspection of the elements.

10 The flow-series or flow-variable form of organization of the work also
12 provides for the location of the machines in the sequence of the technological
14 operations established for the elements to be treated in the given machine line.
16 The production occurs in lots, in which the elements of the various lots may
18 differ somewhat from each other in dimensions and construction, but lending
20 themselves to treatment on one and the same equipment. The production process
22 proceeds in such a way that the time of treatment on the one machine agrees
24 with the time of working on the next machine; the elements of a given lot travel
26 from machine to machine in the sequence of the technological operations, creating
28 continuity of movement. The readjustment of the machines, accessories and tools,
30 and also the modification of the production process, on switching to the
32 treatment of the elements of another lot require careful technical readying
34 and calculation.

36 The straight-flow form of organization of the work, characterized by mass
38 production, provides for the location of the machines in the sequence of the
40 technological operations assigned to particular machines; the elements go from
42 machine to machine piecewise, but the times for carrying out the individual
44 operations are not always the same (or by repeated beat), that is, synchroniza-
46 tion of the time of the operations does not prevail over all of the sections
48 of the lines; consequently there is created, around a machine operating at a
50 longer beat, a bottleneck of untreated elements. This form of working is some-
52 times called pulsating flow.

54 The transfer of the elements between the working places occurs by a roller
56

conveyor, chute, or other nonmechanized transporting means; sometimes conveyors, serving here only as transporting means, are used.

The continuous flow form of organization of the work is only feasible in mass production.

The working places for the machines as well as for the manual operations are distributed within the sequence of the technological operations, where each of the working places carries out one elementary operation. The time allowed for carrying out the individual operations at the working places is accurately specified, and agrees with the productivity and the total course of the production process, so that synchronization of operations and a particular beat for all of the working places are obtained.

Depending on how the beat is regulated and on how the elements are transported several variants of working at continuous flow are in existence:

1. Working in continuous flow with transfer of the products by hand.
2. Working in continuous flow with transfer of the product by simple (non-mechanized) transport means (rollways, slideways, inclines, chutes, etc.). (These and other means are described in Chapter XV, Planning of Intraplant Transport.).
3. Working in continuous flow with predetermined beats, regulated by light or sound signals indicating the lapse of time established for carrying out the operations.
4. Working in continuous flow with periodic feed of the products by mechanical transporters. The transfer of the products from one working place to the other is done with the help of mechanical transport means such as conveyors which are moved periodically or intermittently. The conveyor moves the workpiece after the end of the working operation, while during the actual performance of the operation the conveyor remains at rest. Therefore, the working beat - the duration of the execution of the particular operation - is maintained by the conveyor belt

mechanically.

5. Working at continuous flow with continuous advance by a mechanical transporter. In this case the conveyor is moved continuously and displaces the products lying on it from one working place to the other. As also in the preceding case, the working beat is maintained by the conveyor.

Accordingly the work may be carried out:

(a) Either at the stationary working place around the conveyor; the product is taken off for performing the operation, but nevertheless the conveyor continues to move;

(b) Or at a moving working place, on the conveyor; the product is not taken off, and the operation is carried out while the conveyor is moving.

The forms of organization of the work with continuous flow with periodical feed and continuous feed by mechanical transporters (cases 4 and 5) are regarded as the most highly developed.

For all of the examined cases of working at continuous flow it may be stated that the decisive factor determining the observance of the principle of flow is not mechanical transport but the working beat.

16. Fundamental considerations on organization of working places in shops

At any form of organization of the work, for the purpose of attaining optimal utilization of the equipment and optimal productivity of labor, it is necessary to give careful thought not only to the utilization of all of the technical possibilities of the machines, tools and accessories but also to a rational organization of the working places for assuring continuity of operation of the machines, for which purpose it is necessary to eliminate loss of time and delays due to waste motion and steps, untimely feeding of materials, tools, accessories, untimely repairs, inconvenient location of materials, tools, etc.

A rational organization of the working place involves suitable preliminary readying of the work, timely and precise serving of this place in the working

process, and its best planning and maintenance.

The readying and serving of the working place consist in the following:

(1) Materials, blanks, tools, accessories must be delivered to the working place in good time, before the beginning of the work, in such a way as to avoid delays.

(2) The adjustment of the machines, particularly in large-series and mass production, must be carried out before the beginning of the work; in mass and large-series production the adjustment is carried out by special fixers, and in unit and small-series production by the machinists themselves;

(3) In the working process the delivery of the tools to the working place, the exchange and sharpening, must be carried out in good time by special (auxiliary) workers;

(4) The necessary instruction of the workers before beginning the work and also in the course thereof, as well as the instruction of the supervisory personnel must be timely, and must not delay the work;

(5) The treated elements must be transported regularly (without delay), and without taking the machinist away from his principal work, and without creating any kind of hindrance;

(6) The inspection of the treated elements must as much as possible occur without taking the machinist away from his principal work;

(7) The inspection, verification and repairing of the equipment must occur regularly, at predetermined intervals, and during particular times, in such a way that the normal operation of the machines is not disturbed outside of these intervals, and that stoppage of the work and the machines is avoided.

The rational planning of the work place, that is, the relative location of worker, machine, materials (blanks), tools, accessories, depends on the character of the work to be carried out and the form of its organization.

The planning of the working place must satisfy the following conditions:

(1) In the working process the workers must not make waste motions and steps;

(2) There must not be loss of time or fatiguing of the worker due to an irrational relative location of all of the factors entering into the composition of the working place;

(3) While working at carrying out the various manipulations the worker must not experience any inconvenience or constraint;

(4) Tools, drawings, instruction charts, etc. must be immediately accessible for avoiding interruptions of the work;

(5) All of the tools must be divided into groups, and each tool must have its own place;

(6) In the forms of organization of the work at which the elements are transferred in lots from machine to machine, it is necessary, for avoidance of constraint of the motions of the worker, to provide sufficient space for temporary placement of elements;

(7) The relative location of all the parts of the working place must with the help of corresponding means assure the safety of the worker during the working time;

(8) There must be assured favorable sanitary-technical working conditions with respect to light, air, heat, cleanness, etc.;

(9) At multiple-machine operation the location of the machines served simultaneously must be such that a minimum of time is lost in changing from one machine to another.

It must be borne in mind that the more rational the organization of the working place is, that is, the better the readying, the serving, the planning and the maintenance of the working place is, the smaller is the nonproductive loss of time and the higher is the utilization of the equipment and the productivity of the labor.

17. Basic Principles of the Planning of Technological Processes

Technological process is here defined as the successive changes in form and state of the material or semifinished product for the purpose of obtaining the final form of quality of element or product.

The technological process of the treatment of the individual element is one of the steps in the over-all process of production of the entire machine (product). The production process is subdivided into the following steps:

(1) Blanking of the element - casting, forging, stamping or blanking from rolled material;

(2) Treatment of the element on metal-cutting machines for obtaining the element with the final dimensions and shape;

(3) Manual fitting treatment and matching of the part to its place in the assembly; in mass production this is unnecessary, since, due to the use of limit calipers in the treatment on the machine, interchangeability of the elements is ensured. In series production, these operations are carried out to a small extent, and in unit (individual) production to a large extent;

(4) Assembling of parts and aggregates (or mechanisms) - uniting of individual elements into subparts and parts, and of parts to aggregates (or mechanisms);

(5) Final assembly of the entire machine (product);

(6) Regulating and testing of the machine;

(7) Painting and finishing of the machine.

It should be noted that the painting is advantageously subdivided into several operations carried out in various states of the technological process (priming, filling, and first coat of the castings, painting of the treated elements, final painting of the whole machine).

Completion of each of the stages of the production process is followed the corresponding inspection for verifying that the technical specifications applying to the production in the given stage have been observed and that the finished product is of the required quality.

As shown below, in each stage of the technological process the processed elements and products are verified for accuracy and quality in separate operations.

Since the whole machine is composed of individual elements treated on mechanical machines, such treatment must fully meet the requirements applying to the elements with respect to accuracy of treatment, cleanliness of the surface, relative position of axis and surface, correctness of contours, etc. The technological process of the treatments of the elements must be composed and executed in such a way as to satisfy the requirements assuring proper functioning of the assembled machine.

The fundamental requirements applying to the technological process specify that the process of treatment is to be carried out with proper and most complete utilization of all technical possibilities of the machines, tools, and accessories under the best conditions of cutting the metal attainable with the given machine, the lowest expenditure of time, and the lowest cost of treatment.

The planning of the technological process of the treatment of elements consists in settling the following principal questions:

- (1) Determination of the sizes of the lots of the elements;
- (2) Selection of the kinds of blanks to be used and determination of their dimensions;
- (3) Formulation of different plans and methods of mechanical treatment of the surfaces of the elements, with an indication of the sequence of the technological operations;
- (4) Selection of the types and determination of the dimensions of the

machines, accessories, cutting tools and measuring implements, and also determination of the necessary numbers thereof for carrying out the intended treatments;

(5) Determination of the dimensions of the treated surfaces of the elements;

(6) Determination of the conditions of cutting the metals on the selected machines in each of the operations;

(7) Determination of the time norms of the treatments;

(8) Determination of the classification of the operations.

As stated above, for series and mass production the technological process of the processing of the elements is formulated in detail with clarification of all of the stated factors composing the technological process. In individual production the technological process is not formulated in such detail; here there is composed only a schematic plan of the process of the treatments - the list of operations, with indication of the sequence of the operations, equipments, accessories, cutting tools, measuring implement, and approximate sum of the times necessary for the treatments.

These questions, constituting the content of the technological processes of the mechanical treatment of elements, are examined in detail in the courses on the "Technology of machine-building". Here there will be examined only the fundamental considerations for the decision of these questions, the methods of deciding them applied to problems of planning, the sequence and volume of their contents, and the sequence of their formulation into the technological documentation.

A. Determination of sizes of lots of elements

The characteristic particularity of series production, as already shown, is the production of products in series (lots) taken in production simultaneously.

(A "lot" is here defined as the number of elements and a "series" as the number of machines taken into production simultaneously. The number of elements

in the lot and the number of machines in the series may be different.) The technical-economic superiority of series production over unit production consists in that each of the lots of elements is taken into production simultaneously, for which there are advantageously widely employed special accessories and special cutting tools and measuring implements. Further, the costs of readying and adjustment of the measures are distributed over the number of elements entering into the given lot.

The sizes of the lots of the elements entering into the production is established on the basis of the list of the different kinds of produced products and the yearly number of products of each type and size; the number of the necessary output of products (from the date of the order); the complexity of the given production; the duration of the treatments of the elements and the assembly of the machines; the complexity, duration and cost of the adjustment of the machines; the existence of supplies of materials.

At the selection of the size of a lot of elements there arises the question of how advantageous and profitable it would be to take it in a size greater than the demand for the details in a particular interval of time, since the expenditure of materials for the production of elements must also take into account the average length of time during which the materials are out of circulation, that is, without turnover. On the other hand, however, it is known that at increasing the number of elements in one lot the time and cost of readying for treatment for one element is decreased, so that the size of the lot must be such that these factors are the most favorable, that is, that the necessary materials and means expended on the elements are utilized as quickly as possible, and that the costs of the adjustments referred to one element are minimal. The lot (or series) satisfying these conditions is called optimal.

The influence of the mentioned factors can be seen from an examination of the cost of production of one element.

If:

C is the production cost of the lot of elements;

n is the number of elements in the lot;

s is the piece cost of one element, composed of the cost of the material, wages and overhead;

E is the cost of the adjustment for the production of the whole lot;

c is the production cost of one element at the production of the lot;

then

$$C = ns + E \quad (2)$$

$$c = \frac{C}{n} = s + \frac{E}{n} \quad (3)$$

Long storage of elements brings about the necessity of a surplus quantity of materials present in production, increases the requirement of working capital, and also of unfinished production, or, in other words, decreases the turnover of the liquid assets.

If there are taken into account only the mentioned considerations, then in this respect the most favorable will be the case in which the number of elements in the lot is taken as the number required by the assembly shop for the number of machines to be assembled; in this period the production of lots must be such as to assure that elements will go to storage only at the moment when their supply has been exhausted by the assembly shop. On the other hand, however, in formula (3) the member E/n shows that the larger the number of elements in the lot is, the smaller is the cost of the adjustment referred to 1 piece. This magnitude, generally speaking, has the most important significance; sometimes, however, it is less important that an increased requirement of circulating material, and in this case it becomes necessary to take the lot only

in a size which will assure uninterrupted assembly and regular output of the necessary number of machines.

For determining the size of the lots the literature contains several formulas proposed by various authors. But in view of the difficulties in the determination of the magnitudes entering into their parameters, and also in view of the different production and organization conditions employed in the planning of technological processes and shops, also under industrial conditions, the size of the lot is determined from the calculation of the capacity of the assembly shop, and in a size which assures uninterrupted steady assembly.

The capacity of an assembly shop in the planning of a new enterprise is established on the bases of the programmatic yearly number of pieces to be produced uniformly in the course of a year in equal series. The number of elements kept in intermediate storage in supply must assure uninterrupted assembly; it depends on the form of the production and on the quality of organization of the work in the shops. A normal supply of elements in intermediate storage for series production may be regarded as 10 days, at which, of course, the supply will not be the same for all of the elements: for large-series 2-3 days; for small-series 5-10 days. The better the organization of the work in the shops is, the smaller may be the supply of elements in storage. On the basis of these considerations and the yearly number of the various elements, and taking into account the supply lots, there can be established the number of elements for the stated periods (in the limits of the stated number of days); this number also determines the sizes of the lots.

Therefore, according to this simplified method the number of elements in the lots may be expressed by the following formula:

$$n = \frac{Dt}{\Phi} \quad (4)$$

STAT

where n is the number of elements in the lot;

D is the number of parts according to the yearly program, including the supply parts;

t is the number of days during which the supply of elements is kept in storage;

ϕ is the number of working days per annum.

B. Selection and production of blanks

As blanks for the production of the elements the following may be defined:

- (1) Castings of iron, steel, nonferrous metals;
- (2) Forgings and stampings;
- (3) Blanks of rolled metals - steel, iron, nonferrous metals.

The selection of the particular form of the blanks depends on the structural form of the elements, their purpose, and their service conditions in the fully assembled machine.

Blanks in the form of forgings made in hammer forges and stampings made in dies are employed for elements subjected principally to bending, stretching, twisting, and to considerable variations in the cross sections of the parts. In the production of forgings, one of the main goals is a configuration of the blank approaching the simplified configuration of the element.

For proper decision in particular cases it is necessary to analyze which is better: to give a simplified configuration to the blank and remove the surplus material by mechanical treatment on machines, or to give a more precise configuration and dimensions to the blank approaching that of the finished elements, and remove less metal by machining.

Blanks in the form of forgings are employed principally for large parts and, in unit and small-series production, also for small parts.

Blanks in the form of stampings are obtained by forging in dies; this method of production is greatly superior to that of hammer forging. In stamped

blanks the structure of the metal is more homogeneous, so that the element is stronger. By stamping there are obtained dimensions closer to the final dimensions; in some works stamped blanks are used with very little further mechanical treatment or none at all. In the production of stampings the metal is utilized better, and a small quantity of it is used. The process of producing stampings is carried out much more quickly, and can be performed by less qualified workers. The cost of stamped blanks is less than that of forged blanks.

Blanks in the form of stampings can be employed only when the production program requires large numbers of them, for example, in large-series and mass production, because expensive dies are necessary for the production of such blanks. In this case the cost of the stampings is distributed over a large number of blanks.

The proper decision of the question of the selection in the form of forgings or stampings, when either form is feasible from the viewpoint of the technical requirements, is possible only on the basis of technical-economic calculations for determining the production cost of the element at each of the forms of production.

Blanks made of rolled material (round, square, hexagonal) are employed for elements with a configuration approaching that of the given material, when there does not exist a considerable difference in the cross section of the element, and when it can be obtained in its final form without the removal of much metal. The production of elements from rolled materials is infrequent, except for shafts.

All blanks are made with a tolerance allowance compared with the dimensions of the finished element. This tolerance, consisting of surplus material, is, for obtaining the final dimensions and the finished surfaces of the element, removed by means of mechanical treatments. The surfaces of the element which are not to be treated have no tolerance. (Here there is considered only the technical-

economic significance of tolerances. On the calculation of tolerances compare A. P. Sokolovskii, Course on Technology of Machine Building, part 1, Mashgiz, 1947; V. M. Kovan, Calculation of Treatment Tolerances in Machine Building, Mashgiz, 1953.)

The tolerances must have dimensions sufficient for carrying out the necessary mechanical treatments of the given element, at satisfaction of the stipulated requirements with respect to cleanness and quality of the surfaces of the metal and precision of the dimensions of the element at a minimal cost. Such a tolerance is called the standard tolerance.

Overgenerous tolerances cause excessive expenditures in the production of the element, and thereby increase its production cost, composed of three principal factors: cost of materials, wages for carrying out the treatments, and storage expenses.

The production cost of the element may be expressed in the general form by the following formulas:

$$S = M + P + R \quad (5)$$

or

$$S = M + p t_{st} + (A + J + e + O + Z) \quad (6)$$

where S is the production cost of the element;

M is the cost of the material (after deduction of the valuable scrap);

P is the basic wages for productive work;

R is the shop overhead;

p is the basic wages for productive work per unit time;

t_{st} is the piece time (time for the processing of one element);

A is the amortization of the equipment;

J is the expenditure on tools;

E is the cost of electric energy;

O is the extra charges;

Z is the remaining shop expenses.

At an increased treatment tolerance the weight of the blank is increased, and therewith also the cost of both the blank and the finished element.

The removal of the extra tolerance increases the expenditure of processing time, so that the basic wages for the productive work for the production of one element increase with increasing tolerance. For economizing processing time, therefore, it is desirable to select a tolerance which is removed in one pass.

The overhead entering into the production cost of the element and expressed in percent of the basic wage, also increases with increasing wage.

At an excessive tolerance the weight of the blank and the removal of the shavings are increased, the machines for removing the surplus quantity must work under greater stress, thereby increasing their wear and expenses of repairs.

There is increased the expenditure on cutting tools, because the surplus material is removed in several passes, as a result of which there is increased the basic (technological) time, that is, the service time of the tool, and therewith its expenditure.

The surplus tolerance, by increasing the depth of the cut (depending on the magnitude of the tolerance), requires an increase in the power of the machine, thereby increasing the consumption of electric energy.

The extra charge is applied in percent referred to the basic wage for productive work. Because at an increased tolerance there is increased the basic wage for productive work, the extra charge is increased.

The remaining shop expenses are also, although not to the same extent, increased by an increased tolerance; thus, for example, the costs of transport are increased because of the increased weight of the blanks and the removed

shavings.

As has already been seen, an increased tolerance brings about an increase in all three of the basic factors entering into the cost of the element. Moreover, before proceeding with the treatment of blanks with an increased tolerance the machines must be readjusted, after which their readjustment for other cutting conditions is complicated.

On the other hand, a decreased tolerance makes it impossible to carrying out the necessary mechanical treatments with the desired precision and cleanness, as a result of which there are obtained rejects, which makes the product more expensive.

The standard tolerance assures the necessary mechanical treatment at fulfillment of the corresponding requirements with respect to cleanness and quality of the surfaces of the material and precision of the element; with the standard tolerance, moreover, there are decreased the expenditure of metal, the processing time, and the production cost of the product, and increased the productivity of the equipment.

The established dimensions of the processing tolerances must indicate the permissible deviations from them, that is, referred to the dimensions of the blank because it is impossible to obtain blanks with precisely the established tolerances. The permissible deviations from the tolerances must be small, because at great differences in the dimensions of the blanks there are created great difficulties in the production. In this case it is often necessary to readjust the machines in correspondence with the dimensions of the blanks, besides which there is lowered the precision of the work in the accessories, limited their employment, etc.

In establishing the processing tolerances there is sometimes avoided the production of a precise blank, giving it considerable tolerances, on the assumption that the removal of the surplus metal is more advantageously carried

out on the metal-cutting machines. Such considerations are permissible in individual cases at small-scale production. As already stated, the optimal decision can only be obtained as the result of technical-economic calculations with comparison of the costs of the elements with various forms of blanks. In present day productions of a series or mass character, there exists a definite and wholly rational striving for the smallest possible processing tolerances and the production of blanks requiring the least possible mechanical treatment, and even the production of elements which do not have to be treated for the removal of shavings on metal-cutting machines.

The magnitudes of the processing tolerances and of the permissible dimensional variations of the blanks depends on a number of factors, whose degree of influence is different for different cases; some of these factors are:

- (a) The material of the blank;
- (b) The configuration of the element and its dimensions;
- (c) The character of the blank and the method of its production;
- (d) The requirements with respect to the mechanical treatments;
- (e) The technical conditions with respect to the quality and cleanness of the surfaces and the precision of the dimensions of the element.

The material of the blank. As the material of the blanks there may be employed cast iron, steel castings or castings of nonferrous metals, forgings and stampings from alloyed or carbon steels, forgings from ingots or rolled materials.

With elements obtained by casting the surface layer has a hard skin. For normal working of the tool the depth of the cut must be greater than the thickness of the crust, in correspondence with which the tolerance must be stipulated. The thickness of the crust will vary in dependence on the material, the dimensions of the casting and the method of casting: for castings from gray iron 1-2 mm; for steel castings 1-3 mm.

In the production of forgings a layer of scale is formed, which increases the wear of the cutting tool during treatment. Sometimes this layer is so hard that the tool is unable to work it; therefore the depth of cutting must be greater than the thickness of the scale layer. In the treatment of carbon steel, a cutting depth of 1.5 mm is often sufficient for proper working; for alloyed steels the cutting depth must be 2-4 mm.

The surface layer of stampings is decarbonized, and must be removed during the treatment. The thickness of this layer will vary: in stampings from alloyed steels up to 0.5 mm, in stampings from carbon steel up to 0.5-1.0 mm depending on the configuration and dimensions of the element and on other factors.

Configuration of the blanks and their dimensions. A blank with a complicated configuration is difficult to obtain by hammer forging, so that any simplification in the form of the blank leads to the necessity of increasing the processing tolerances.

In stampings with a complicated configuration, the distribution (flow) of the material in correspondence with the required form of the element is difficult, so that increased tolerances are also necessary for such stampings.

In castings with a complicated configuration for the purpose of attaining a more uniform cooling, the necessity of getting a smooth, gradual transition from the points along the walls toward the interior does not permit sharp variations in the cross section; this requirement leads, of course, to the necessity of increasing the tolerances.

In the production of large castings shrinkage must be expected, which may become very extensive in large-size products; this necessitates increasing the tolerances of such elements.

Form of blank and method of its production. The blanks are in the form of castings, forgings or stampings, or are made of a rolled material.

The castings may be produced in various ways: by means of machine-molding or

0 manual-molding, casting in loam- or metal-mold, casting under pressure.

2 The magnitudes of the tolerances and permissible variations differ in
4 dependence on the form of the blank and its method of production. Thus, for
6 a cast element produced by hand molding the tolerances of the casting will be
8 greater than with a casting produced by machine molding; in precisely the
10 same way, the tolerances of a casting produced in a loam mold will be greater
12 than with a casting produced in a metal mold; the tolerances of a casting pro-
14 duced under pressure will be smaller than with a casting produced in a metal
16 mold.

18 In comparing the tolerances of forgings and stampings for one and the
20 same element it is found that the tolerances are greater with forgings than
22 with stampings.

24 For forgings from castings the tolerances must be greater than for
26 forgings from rolled materials, because on the surface of the castings there
28 are present cracks and blisters, which are decreased in cross section at the
30 rolling.

32 With blanks from rolled materials the tolerances are smaller than with
34 blanks obtained from castings, forgings or stampings; with blanks from rolled
36 materials the tolerances are given only such dimensions as assure the necessary
38 precision and cleanness of the surface obtained after the mechanical treat-
40 ments.

42 In some cases it is necessary to increase the tolerances of the blanks
44 because of the necessity of creating the conditions for the possibility of
46 carrying out the mechanical treatments; thus, for example, with bodies of rotation
48 it is sometimes necessary to stipulate a tolerance for the centering or to
50 increase the length of the blank for enabling it to be fastened in the chucks
52 of the machine.

54 Requirements with respect to mechanical treatments. In correspondence to
56

the requirements relating to the elements with respect to cleanness of surface and precision of dimensions, there is employed one or another method of treatment. For each intermediate operation of the mechanical treatment it is necessary to leave a tolerance. Consequently the total tolerance depends on the methods of the mechanical treatments necessary for producing the element according to the technical conditions.

It must be borne in mind that in thermal treatments the element is somewhat deformed, and its dimensions changed; in this connection, for elements which have to undergo thermal treatments the tolerances for the mechanical treatments must be increased.

Technical conditions with respect to quality of surface of precision of dimensions of elements. The requirements applying to the element in correspondence with the technical conditions determine the magnitudes of the tolerances; the stricter these requirements are, the greater must be the magnitudes of the tolerances. If according to the technical conditions it is necessary that the surface of the metal be clean, wholly free of stratifications, hair cracks (flakes), rough spots, pits, then the tolerances must be increased for the removal of these defects from the surface of the metal. If the surface must be smooth, there must be allowed tolerances enabling the finish treatments after the rough treatments. If the dimensions of the element must be observed precisely within the established tolerances, the tolerances must assure the possibility of the finish treatments, for which their dimensions must be increased.

As can be seen from a consideration of these factors, the normal tolerance must be of such a magnitude that it is possible to carry out the mechanical treatment and obtain the necessary cleanness of the surface and precision of dimensions of the element required by the technical conditions at the lowest cost of the element. From this it follows that the magnitude of the tolerance will depend on the thickness of the surface layer to be removed and the tolerances

necessary for all intermediate operations of the mechanical treatment.

Since the dimensions of the blank may contain allowances for deviations in the dimensions of this blank in the positive and negative directions, it is necessary that, in determining the total magnitude of the tolerance the dimensions of the blank must be supplemented by the magnitude of the possible negative deviation (if such is permitted); otherwise, in the production of a blank with a negative deviation, the dimensions will not be sufficient for the subsequent mechanical treatment.

The magnitude of the tolerance for the treatment is best determined by calculation. (The methods of calculation are explained in the course "Technology of Machine Building".) Under industrial conditions, the dimensions of the tolerances are determined by various practical methods: in dependence on the weight and outside dimensions of the element, on the structural shape and dimensions, and on the necessary precision of treatment. Many works and planned organizations have their Tables of tolerances and permissible variations formulated on the basis of long experience applied to the character of their production; these Tables are usually used in the planning of mechanical shops.

Very convenient for legibility is the graphic representation of the division of tolerance into various stages of the treatment in the form of a schematic diagram, as shown in Fig.32 (for a shaft) and in Fig.33 (for an aperture).

The dimensions of the blank are called free in all cases in which they relate to the untreated surface and show no permissible deviation. The permissible deviation of the blank in the untreated places depends on the kind of blank and the method of its production.

The rejects in the mechanical treatment of metals for various forms of blanks are expressed approximately in the following percentages of the weight of the finished elements:

0
 2 Iron castings.....15-20
 4 Steel castings.....15-20
 6 Bronze castings.....15-20
 8 Forgings.....15-40
 10 Stampings.....10
 12 Rolled steel..... 5

14
 16 The average percentage of rejects of all forms of blanks for mechanical
 18 shops may be taken at 15%.

20
 22 The preparation of the blanks for treatment on the metal-cutting machines
 24 occurs in the same shop where they are produced. The preparation consists in
 26 that the blank is given a state or form in which the mechanical treatment can
 28 be carried out. The preparation has various characters depending on the kind
 30 of blank.

32
 34 Castings, for example, after removal from the molds, are subjected to
 36 chipping and cleaning. The pouring channel, head, deposit and all roughnesses
 38 of the casting are chipped off with the hand chisel and trimmed with the file
 40 or removed with the help of the pneumatic chisel, circular saw or abrasive
 42 disk. The removal from the casting of the mold material burned fast to its
 44 surface occurs in various manners: with a wire brush, with the sandblast ap-
 46 paratus, in the rotating drum, on the abrading machine, by shot-blasting, and
 48 hydraulically.

50
 52 For convenience of stocking and sorting the blanks, and delivering them
 54 to the working places as quickly as possible, and also for avoiding confusion
 56 in the shops and stockrooms, it is necessary to mark the blanks according to
 the system of the particular works. The marking occurs with paints of various
 colors, in the form of symbols, letters or numbers, applied with the paint, or,
 in the form of printed labels, with glue.

Simultaneous and set-wise readying of the blanks assures the quickest and
 most economical execution of the treatments in the mechanical shops. The properly
 readied blanks go directly into the shop stock or to the machines; in the shops they

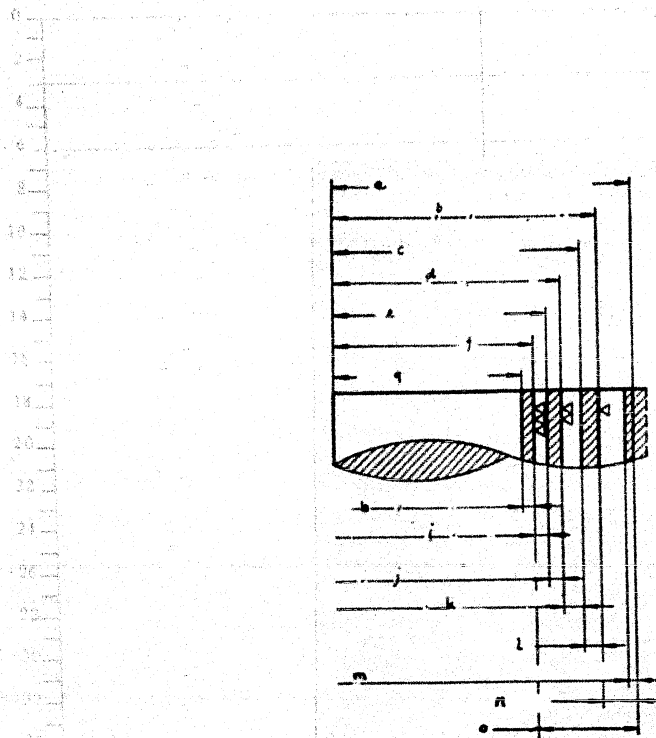


Fig. 32: Scheme of division of tolerance into various stages of treatment of shaft.

(a) nominal dimension of blank; (b) longest dimension before finish turning after rough turning; (c) least dimension before finish turning after rough turning; (d) longest dimension before grinding after finish turning; (e) least dimension before grinding after finish turning; (f) longest final dimension; (g) least final dimension; (h) permissible deviation at grinding; (i) least permissible deviation at grinding; (j) permissible deviation at finish turning; (k) least permissible deviation before finish turning after rough turning; (l) permissible deviation at rough turning; (m) negative part of permissible deviation of blank; (n) permissible deviation before rough turning; (o) total tolerance

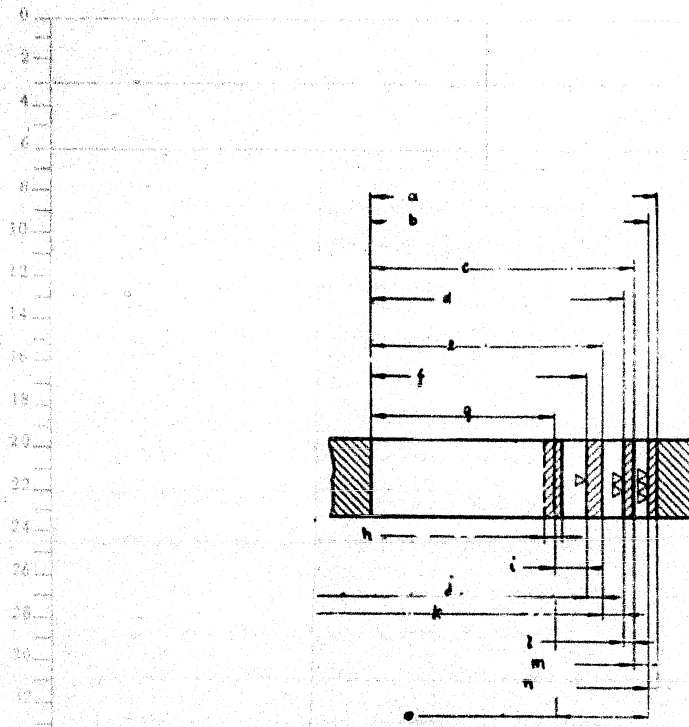


Fig. 33: Scheme of division of tolerance into various stages of treatment of hole.

(a) longest final dimension; (b) least final dimension; (c) longest dimension before grinding after finish boring; (d) least dimension before grinding after finish boring; (e) longest dimension before finish boring after rough boring (drilling); (f) least dimension before finish boring after rough boring (drilling); (g) nominal dimension of blank; (h) positive part of permissible deviation of blank; (i) tolerance for rough boring; (j) permissible deviation at rough boring (drilling); (k) least tolerance at finish boring after rough boring; (l) permissible deviation at finish boring; (m) least tolerance before grinding; (n) permissible deviation at grinding (reaming); (o) total tolerance

do not require any supplementary operations before being treated.

G. Establishment of plan and selection of methods of treatment of elements

Plan and method of treatment. For assuring the most rational process of treatment of the elements there is formulated a differentiated plan the treatments, with indication of the sequence and methods of treatment. In connection with this the whole process of treatment is divided (differentiated) into individual operations. The operations are divided between the machines and the transporters. The transporters are composed of individual subtransporters.

At treatment on multi-spindle semiautomatic and automatic machines the elements fastened to each of them occupy various positions relative to the machine by means of a rotating table (or drum), which brings the elements to the various tools in succession. Each of the positions which the element occupies relatively to the machine at its fixed fastening is called the position.

In the plan of the mechanical treatments there are also included the other control, intermediate fitter and other operations necessary for the further mechanical treatments; finally, the operations for the other forms of work after the mechanical treatments are included in the plans of the corresponding treatments.

The operations and transfers are given serial numbers, at which the operations are denoted with Roman numbers and the transfers with Arabic numbers. The serial numbers for the transfers are given for each of the operations independently, beginning with the first number. The machines are denoted by letters, at which in each of the operations the alphabetical denotation begins with the first letter of the alphabet. The transfers are not denoted, but the number of them is indicated.

The operations are formulated briefly according to the kind of treatment, for example: lathing, milling-cutting, drilling, grinding, etc; the transfers are described in detail with indication of the surface to be treated - its name, serial number or size.

For a more legible and precise representation of the plan and the methods of treatment the technological process is illustrated by graphic depictions (detail sketches) of the transitions of the treatments with schematic indication of the method of fastening the element on the machine, the position of the element, device, tool and place of treatment; the latter are indicated by heavy lines or numbers. The excisions are given for each of the transitions separately. The graphic representations of the transitions for various forms of treatment with indication of the position of element and tool are given in figures 34-37.

Selection of methods of treatment. The selection of the method of treatment depends on the required precision of the given element.

For the proper collaboration between the parts of the machine constituting a kinematic train of construction there must be attained the required precision of the dimensions of the elements and of the dimensions determining their relative positions in the whole construction, that is, there must exist the precision of the dimensional train following from the constructional connections of the machine and determined by the particular requirements of the elements with respect to dimensions and shape.

For fulfilling these requirements it is necessary, in order to avoid cumulative errors, to begin the treatment of the element at some starting surface constituting an established base. (Further details on such bases will be found in the course "Technology of Machine Building".)

The greatest precision of treatment can be attained when the whole process of treatment is begun from the same base with the same machine, because, owing to the possibility of displacements, with each new machine there is introduced an error in the dimension of the relative positions of axis and surface. Since in the majority of cases it is impossible to carry out the whole treatment of the element on the same machine, and it is necessary to continue to treatment on the machines of other types, therefore, in order to attain the greatest precision

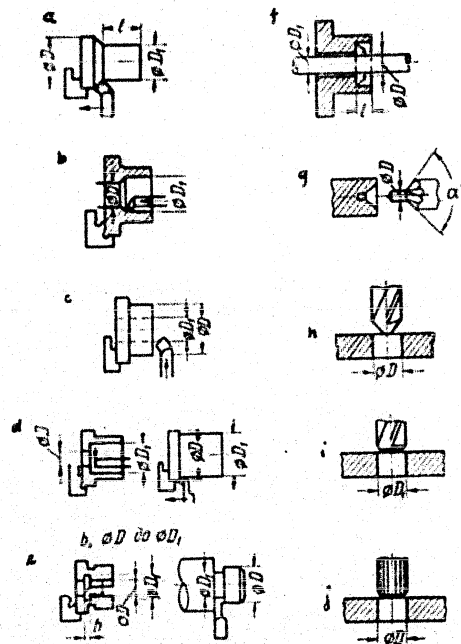


Fig. 34: Exsisions of transitions with indication of position of element and tool. (a) turning ϕD to ϕD_1 rough (finished); (b) boring ϕD to ϕD_1 rough (finished); (c) undercutting face ϕD to ϕD_1 rough (finished); (d) undercutting ledge ϕD to ϕD_1 rough (finished); (e) boring excavation width b , ϕD to ϕD_1 ; (f) boring point blank to depth L rough (finished); (g) centering ϕD x A° ; (h) drilling ϕD hole; (i) countersinking hole; (j) reaming hole ϕD (permissible deviation) rough (finished)

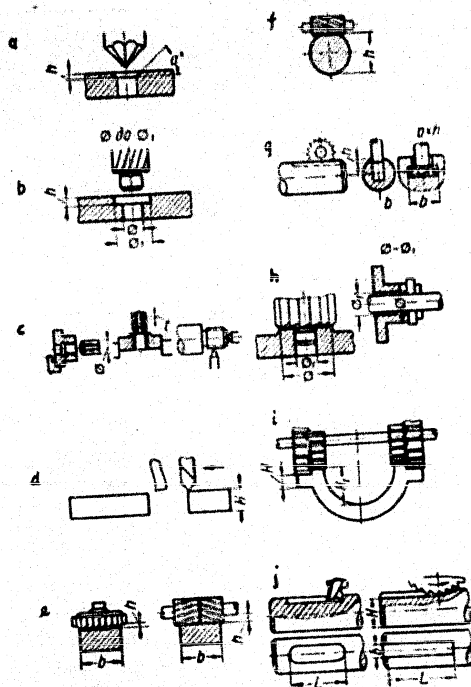


Fig. 35: Excisions of transitions with indication of position of element and tool. (a) countersinking facet $A^\circ \times h$ mm, ledge of depth h , ϕ to ϕ_1 ; (b) countersinking ledge of depth h , ϕ to ϕ_1 ; (c) male threading ϕ ut (pitch or number of threads to 1" with cutter, female threader, male threader rough, calibrating, etc.); (d) planing area b , size H , rough (finished); (e) milling-cutting area $b \times L$, rough (finished); (f) milling-cutting flatwork, rough (finished); (g) milling-cutting groove (T-form keyway); (h) facing ϕ - ϕ_1 ; (i) milling 4 areas with set of milling cutters, rough (finished); (j) milling keyway $b \times L$ in dimension H , rough (finished)

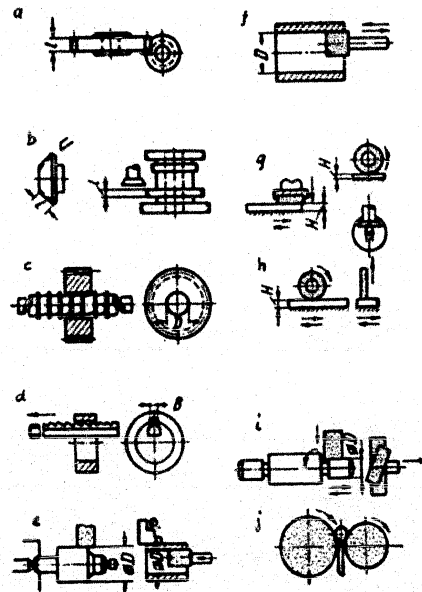


Fig. 36: Excisions of transitions with indication of positions of element and tool. (a) milling teeth $M \times L \times Z$, rough (finished); (b) chiseling teeth $M \times L \times Z$, rough (finished); (c) broaching hole ϕD (ϕD_1 to ϕD), rough (finished); (d) broaching excavation (keyway) of width B , rough (finished); (e) grinding above, inside (face, cone, plane, etc.), ϕD or $b \times l$; (f) grinding hole ϕD (ϕD_1 to ϕD), rough (finished); (g) grinding plane of dimension H , rough (finished); (h) grinding on centerless grinding machine cylinder (neck) of ϕD (ϕD_1 to ϕD), rough (finished)

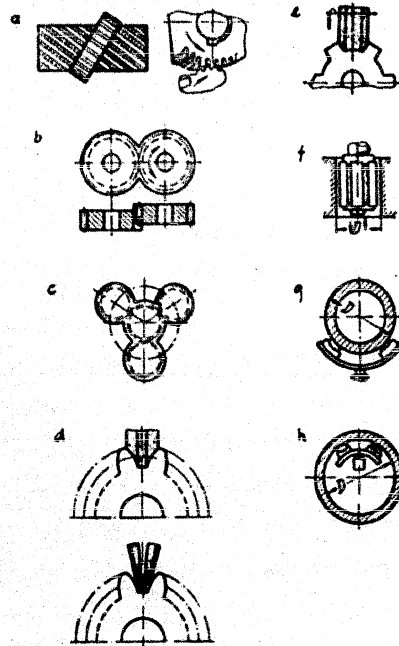


Fig. 37: Excisions of transitions with indication of position of element and tool. (a) grinding teeth of gear; (b) generating teeth of gear; (c) fit-grinding teeth of gear; (d) grinding teeth of gear; (e) grinding slot; (f) honing hole of ϕD , rough (finished); (g) superfinishing cylinder (neck) of ϕD ; (h) superfinishing hole of ϕD

it is necessary for the treatments on all of the machines to carry out as much as possible from the same base. If this is impossible because of the character

of the treatments, and it is necessary to take as the base some other surface, then, as the new base, the surface to be treated must be taken which is determined by the precise dimensions with respect to the surface which has the greatest influence on the action of the element in the assembled machine.

The dimensions of the base must be such as to make it possible to obtain a secure fastening of the element fixed in position during the treatment; the base surface must be strong and resistant to deformation by forces to which it might be exposed during cutting of the metal.

The treatment of the element must begin with the surface which will serve as the established base for further operations. For the treatment of this surface, that is, for carrying out the first operation, an untreated surface which is as clean, smooth and level as possible must be taken as the base. Further, when the established surface has been treated, the rest of the surfaces are treated, going from the less to the more precise; the more precise a surface must be, the later must it be treated. The last to be treated is the surface which must be the most precise and has the greatest importance for proper functioning of the element. If, because of the conditions of the treatment, this surface must be treated earlier, then it must receive a second treatment for giving it its final dimensions.

If in the execution of the operations there exists the possibility of obtaining rejects on account of the specific conditions of the treatment, then these operations should as much as possible be carried out earlier, which eliminates extra work.

In view of the fact that the attainment of absolute precision of dimensions under industrial conditions is impossible and that the precision of the treatments varies in dependence on a number of factors, the treatments on the machines are carried out at so-called economic precision, that is, at a precision which, at a minimal cost of the treatment, is obtained under normal industrial condi-

tions at working on good machines with employment of the necessary devices, cutting tools and measuring implements at normal expenditure of time and normal qualifications of the workers, corresponding to the character of the work. The factors having an influence on the precision of the treatment on metal-cutting machines are many, and it would be impossible to enumerate all of them here. The principal ones are as follows:

1. Inaccuracies of the machine, due to defective guides of the machine, unusually great play in bearings and guides, out-of-round of spindle journals, disturbance of perpendicularity or parallelism of the axis, insufficient rigidity of machine elements and deformation of them, improper or inaccurate motion screws, etc.
2. Inaccuracies in clamping the element on the machine or in the device; insufficiently strong fastening of the element, improper position of the element relative to the axis of the spindle, etc.
3. Inaccuracies due to the tool: improper or inaccurate setting, imprecisions of its fabrication, wear in service, deformation and heating during cutting of the metal.
4. Measurement errors due to improper use of implements, inaccuracies of such devices, influence of temperature, etc.
5. Deformation of elements during treatment, due to disturbance of the state of internal strain produced by removing of surface layer, heating of element during treatment, insufficient rigidity of the element.
6. Quality of surface after treatment due to inaccurate measurements.
7. Errors in execution of the work.

The necessary degree of precision of treatment in correspondence with the requirements for the given class is attained on different machines in different ways.

Thus the precision of treatment of a hole of the 2nd class is obtained by finish-reaming, grinding, lapping, mechanical lapping with an abrasive head (honoring process), broaching, mechanical lapping with a vibrating bar (process of

superfinishing); with the same methods there can also be obtained precision of the 1st-class, but with well-checked unworn machines in good condition.

Treatment of holes according to the 3rd-class is obtained by drilling followed by finish-reaming; the same precision can also be obtained by finish-cutting with machines in perfect condition and at careful working; the same precision, and more economically, can also be obtained by grinding provided this is possible according to the character of the treatment.

Holes of the 4th-class precision can be carried out by boring with a finish-cutter on the lathe or turret lathe or by drilling with the help of the jig.

Holes of the 5th-class precision can be obtained by finish-drilling or finish-boring on any machine, including automatic, suitable for such operations.

Precision of treatment of shafts of the 1st-class after preliminary lathing is obtained by grinding: preliminary - rough and final - finish at slow feed.

For treatment of shafts according to 2nd-class precision there is as a general rule employed grinding after preliminary treatment with the lathe or turret lathe. This precision can also be obtained without the employment of grinding by working with finishing cutters on the lathe or turret lathe by workers with sufficiently high qualifications.

Treatment of shafts with the 3rd-class precision can be obtained on the lathe (in perfect condition) with finishing cutters in the absence of sagging, which can be obtained by the employment of supports. As a general rule, however, the most economical method for large-scale production consists in the treatment of shafts of this class of precision by grinding.

Shafts of the 4th-class precision are treated on the lathe or turret lathe, and also on automatic machines at employment of finishing cutters.

The treatment of shafts according to the 5th-class precision can be

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carried out on the lathe or turret lathe without employment of special accessories; the treatment of long shafts, however, must occur with finishing cutters with employment of supporting arrangements.

The selection of the method treatment depends on the precision specified for the given element. The selection of the method necessarily takes into account the economic feasibility of its employment. In cases where a precise treatment is not required, and a coarse treatment is sufficient, a precise method of treatment should not be employed, since this only makes the product more expensive.

The principal method (although not the only one) for obtaining the highest precision of treatment is grinding, with which it is comparatively easy and economical to attain 2nd-class precision, and at careful working, also 1st-class. The main advantage of grinding over treatment with cutters consists in that at grinding it is possible to remove from the surface of the product very fine cuttings, and in this way bring the element to the required dimensions. The cuttings removed by cutters are thick, and cannot be as fine as at grinding, because a cutter is unable to remove cuttings smaller than a certain thickness. The precision of the treatment with a cutter also depends on its wear.

At the treatment with cutters on the lathe there occur imprecisions which do not occur at working on the grinding machine; the center of the headstock of the lathe at the treatment rotates together with the element, and if the center of the stock has a deflection the center of the section of the rotating shaft does not coincide with the axis of the central hole, and the shaft will be eccentric when placed in another center. In the grinding machine both centers are stationary, so that this imprecision does not occur.

At treatment on the lathe the surface cannot be as level and smooth as after grinding; this also increases the imprecision.

All this leads to the conclusion that final treatment on the grinding

machine is always better than final facing.

In exactly the same way at flat grinding it is easier to obtain precise dimensions than at planing or milling, because in this case the thickness of the cuttings cannot be extremely small. The employment of grinding is also possible for such shaping operations as thread-cutting and processing the teeth of cogwheels, whose precision is very important to the operation of the mechanism.

Sufficiently high precision of treatment can also be obtained with other, very diverse methods, as, for example, by the employment of reaming, broaching, fine (diamond) facing and boring, mechanical rubbing with the abrasive head (honing), lapping, mechanical rubbing with the vibrating abrasive block (super-finishing).

The possible precision attained with the various methods of treatment may be arranged in the following sequence:

- (a) Finish-facing of elements of small dimensions followed by finishing with emery paper - up to 0.02 mm;
- (b) Fine-grinding - up to 0.005 mm;
- (c) Precision-grinding - up to 0.0025 mm;
- (d) Lapping - up to 0.0005 mm (which is the limit of industrial treatment).

On the basis of experimental data there have been compiled tables of the average values of the economical precision of the various methods of treatment; these tables are used at the formulation of technological processes.

D. Selection of equipments, accessories, cutting tools, measuring implements

The plan and the methods of treatment of the elements established at the formulation of the technological process also indicate the machines to be employed for the various operations; at this there must also be enumerated the characteristics of the given machine: its name, builder, type, mark and principal dimensions.

At the planning of the technological processes it is necessary to have available all of the data characterizing the equipments which will be required by the future enterprise. For this purpose it is necessary to have the certificates of the machines. The certificate gives the complete characterization of the machine determining its industrial possibilities and technical capabilities if it is present in use. The certificate is composed according to an established form for each kind of machine.

If at the planning of the technological process the certificate of a contemplated new equipment is not available, there is used the information on it from the corresponding catalog.

The selection of the type of machine is determined before all by the possibility of assuring the fulfilment of the technical requirements applying to the element to be treated with respect to precision of its dimensions, the form and finish of its surfaces. If according to the character of the treatment the fulfilment of these requirements is possible with several different machines, then the selection of the machine for carrying out the particular operation must be on the basis of the following considerations:

- (1) The correspondence of the principal dimensions of the machine to the overall dimensions of one or more elements to be treated;
- (2) The correspondence of the productivity of the machine to the number of elements to be treated per annum;
- (3) Minimal expenditure of time on the treatment;
- (4) Most economical cost of the treatment;
- (5) The greatest possible utilization of the machine with respect to power and time;
- (6) Low cost of the machine;
- (7) The real possibility of acquiring one or another machine;
- (8) The necessity of using existing machines.

The selection of the type of machine is considerably influenced by the necessary degree of precision of the dimensions and form of the element and the finish of its treated surfaces; the higher these requirements are, the more expensive is the machine, the greater is the treating time, the higher are the qualifications of the workers, and consequently the higher is the cost of the whole treatment. Therefore, the degree of precision and finish of the surfaces of the element must be determined solely on the basis of the constructional and operational conditions of its functions. Insufficient precision may worsen the quality of the machine, but at the same time, excessive precision makes the machine more expensive, and, where this is not required by the character of the construction, an increased precision leads to negative results: the output of the production in the same interval of time will be smaller and its cost higher.

The selection of the machine should occur in correspondence with the dimensions of the element to be treated, in order to utilize all of the technical possibilities and power of the machine as completely as possible. For this purpose it is necessary that the power expended on the removal of the cuttings come as close as possible to the power of the machine.

In the economy of the technological process a very important role is played by the productivity of the machine, because the machine must be utilized as completely as possible also with respect to its loading in time. Sometimes, however, it is advantageous to adopt a machine with a higher productivity even when its loading in time is incomplete, if at this the cost of the treatment is lower than on another machine even when loaded to capacity.

At the selection of the machines there must also be taken into its cost, because the latter also has an influence on the production cost of the product.

As can be seen, the decisive factor in the selection between several machines (if the performance of the given operation on different machines

assuring satisfaction of the technical requirements applying to the element) is the economy of the process of treatment.

In this case for deciding the question of the machine to be selected for the performance of the given operation there should be compared the economy of the treatment on the different machines, taking as the criteria the following factors:

- (1) The time expended on the treatment of the element, or the productivity of the machine;
- (2) The capital investment necessary for the production of the given number of elements;
- (3) The cost of treatment of the element;
- (4) The period after which the cost of the more expensive machine is repaid.

The time expended on the treatment of the element - the piece time - serves as the first criterion, which is often used at the planning of the technological processes for the selection of the machine. This time determines the cost of the treatment, and at the comparison in this respect of two machines there is selected the one on which, at assurance of fulfilment of the particular conditions of the treatment, the expenditure of time is smaller.

This procedure, while being the simplest and the most widely employed, does not always provide the correct decision of the question of the cost of the treatment, which is the decisive factor. What is here concerned is that the time of treatment is one of several functions of the cost of treatment and is influenced by other functions, which may be predominant.

The cost of treatment of the element on a given machine (complete treatment in one or more operations) is composed of the wage and the shop overhead: it may be expressed in general form by the following formula

$$S_0 = P + R$$

(7)

Where S_0 is the cost of treatment of the element;

P is the basic wage for the productive work for the treatment of the element;

R is the shop overhead.

The wage for the treatment of the detail equals the wage per unit time and the treatment time - piece time, that is:

$$P = p t_{st}$$

(8)

From this formula it follows that:

(1) The wage for the treatment of the element may be greater at working on one of the compared machines if the piece time at working on this machine is greater but the wage per unit time is the same in both cases;

(2) The wage for the treatment of the element may be greater at working on one of the compared machines if the piece time is the same for both cases but the wage per unit time on the one machine is greater than on the other;

(3) The wage for the treatment of the detail may be greater at working on one of the compared machines even when the piece time at the treatment is smaller but the wage per unit time is considerably greater than on the other.

From this it follows that the magnitude of the piece time does not yet determine on which of the machines the wage will be smaller.

Moreover, the magnitude of the shop overhead also depends on the type of machine, as can be seen from the composition of this expense. The items of the overhead entering into the shop cost of treatment of the elements includes (amortization of the equipment (machines and accessories); expenditures on tools (cost of sharpening and amortization); cost of electricity (fuel - at

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heat treatments); extra charges above basic wage of productive work, and also other items of shop overhead ((compare(equ. 6))).

The amortization of the equipment, calculated in a particular percentage per annum of the cost of the equipment, is reflected in the cost of treatment of the elements. The more expensive the machines and accessories are, the greater is the total amortization, and hence also the cost of treatment. However, this is only true if the productivity of the more expensive machine does not differ much from the productivity of the less expensive machine.

With increasing expenditure on tools there also increases in direct dependence of the cost of the treatment; therefore at the planning of the technological process of treatment of a given element it must be sought to employ the most productive machines, accessories and tools at the lowest cost thereof, although not to the detriment of quality required for the given detail.

The cost of electricity varies with the different machines, so that the cost of electricity depends on the particular type of machine.

The extra charge above the basic wage for productive work is made in a percentage of the latter established for each kind of production; therefore the greater the wage is the greater also will be the extra charge, while the amount of the actual wage depends on the time expended on the treatment at the given form of equipment and qualifications of the workers necessary for the given work. Consequently, the machine selected for the treatment also has an influence on the magnitude of the extra charge above the basic wage.

The other items of shop overhead relate to expenditures principally in connection with the utilization of the shop; here there belong the expenditures on auxiliary materials, the wages of auxiliary workers, administrative-technical and accounting-office personnel, expenditures on heating, lighting, water, supplementary wages, etc. The absolute amounts of these expenditures according to the shops (with the exception of some of them) does not depend on the

type of machines, and it is only on some of them that the types of the machines show an influence; therefore in comparing the costs of treatment on various machines these expenditures may be regarded as approximately equal.

Under real conditions of productions it is impossible how the sum of these shop expenditures is related to each of the machines, so that in comparing the costs of the treatments a percentage of their sum is allocated to the respective basic wages of the productive operations. The percentages are calculated on the basis of the total sum of the expenditures and the total amount of the basic wages of productive workers by shops. Since on the type of machine, as already shown above, there depends the amount of the basic wage of the productive workers, therefore the shop overhead applied to a given machine, taken as a percentage referred to the basic wage of the productive workers, also depends on the selected machine.

Substituting in formula (7) the values P and R (from formulas (8) and (6)) gives:

$$S_o = P + R = pt_{st} + (A + J + \epsilon + O + Z) \quad (9)$$

From this formula it can be seen that, the magnitude of the treating time being only one of several factors having an influence on the cost of the treatment, it is impossible to give a proper and precise decision on the advantages of the treatment on one of the compared machines; it may be regarded as only a first approximate decision. Comparison of the time required for the treatment of the element at each of the compared methods does not yet give an adequate idea of the economy of the respective method, because not only the time but also other factors have an influence on the cost of the treatment; the wage, the expenditures on tools for the equipments and accessories, the cost of electricity, and other items of the shop overhead. Despite its insufficient precision from the economic viewpoint, however, comparison of the times is often

employed for the approximate evaluation of several alternative methods of treatment. Such a procedure at the formulation of the technological process gives the possibility of deciding the question comparatively quickly and simply; but whenever it is necessary to have a wholly precise and correct judgment on the economic feasibility of the selected method it is necessary, in taking into account all of the factors having an influence on the cost of the treatment, to make a detailed calculation for each of the compared methods, and to select from them the most economical one.

The productivity of the machine, expressed in the number of elements or products turned out per unit time, is a magnitude the inverse of the piece time, that is

$$N = \frac{1}{t_{st}} \quad (10)$$

where N is the number of elements or products turned out per unit time.

The number of elements turned out per shift at an 8-hour working day is

$$N_{ca} = \frac{480}{t_{st}} \quad (11)$$

Since the magnitude of the productivity of the machine depends only on the piece time, therefore the consideration of the selection between several machines consists substantially in a consideration on the basis of the treating time, which, as can be seen from the foregoing, does not yet furnish an adequate idea of the economy of the method of treatment.

The selection of the one or the other machine on the basis of a comparison of the expenditures which will have to be made for the production of the given number of elements consists in that for each of these machines there is calculated the expenditures which have to be made for the fulfilment of the established

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program in a particular interval of time. The expenditures are calculated as a whole on the total number of elements to be produced. Into them there enter the basic wages of the productive workers and the shop overhead, the amortization of the machines and accessories, the expenditures on tools, electricity, the surcharge on the basic wage, and other expenditures.

The best criterion for the selection of the machine is the comparison of the cost of treatment on the compared machines provided that at this it is possible on each of them to fulfill the technical requirements applying to the element with respect to the precision and finish of the treated surface. This method requires the longest calculation, because here there must be made complete calculations of the wages and shop overhead for the production of the given element, which is difficult at the planning of the technological process of this element in the absence of some of the necessary information.

A precise calculation of the cost of the treatment is particularly necessary for the comparison of operations on machines requiring complicated tooling, whose cost must be included in the calculation. This applies particularly to automatic, semiautomatic, aggregated machines. In this case there must be made comparative calculations of the costs of the treatments. For this purpose it is necessary to know not only the norms of the treating times but also the shop overhead on each of the compared machines, which is often very complicated.

The cost of the tooling referred to one element depends on the number of elements to be treated for one tooling, or, in other words, depends on the number of details in the lot. The larger the number of elements in the lot is, the smaller is the share of the tooling of the machine allocated to one element, and hence the smaller is the cost of the treatment of the elements on the given machine. At some number of elements in the lot the cost of the treatment will be the same on two compared machines, or at another number of details the cost of the treatment will be greater or smaller on one of these machines,

so that the equation of the cost of the treatment of the lot of the elements can be constructed for each of the two machines.

Let y be the total cost of treatment of the lot of elements on the first machine; x the number of elements in the lot; S_1 the piece cost of treatment of the details on the first machine equal to the basic wage plus overhead per unit time; E_1 the cost of tooling of the first machine equal to the wage for the productive tooling time plus overhead per unit time.

The cost of tooling of the machine is a constant value for the given machine and is independent of the number of elements in the lot. Then the total cost of treatment of the lot of elements on the first machine is

$$y = S_1 x + E_1 \quad (12)$$

Analogously the total cost of treatment of the lot of details on the second machine is

$$y = S_2 x + E_2 \quad (13)$$

As can be seen, each of the equations is the equation of a straight.

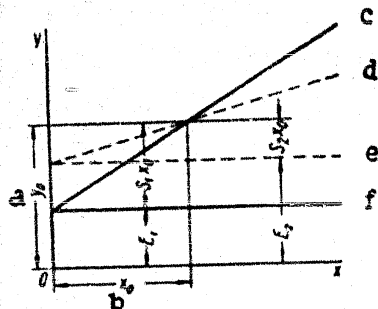
If in coordinate axes there is laid out on the abscissa axis the number of elements x in the lot and on the ordinate the cost of treatment of the lot of elements y , there are obtained the positions of the straights for the first and second machines (Fig. 38).

Then the point of intersection of the straights (x_0, y_0) determines the number of elements in the lot equals x_0 at which the cost of treatment of the lot equals y_0 will be the same on both machines.

At a number of elements in the lot smaller than x_0 the cost of treatment will be smaller on the first machine and at a number of elements greater than

x_0 than cost of treatment will be smaller on the second machine.

By writing equations (12) and (13) for the points x_0 , y_0 and comparing them there can be determined x :



$$\left. \begin{aligned} y_0 &= S_1 x_0 + E_1 = S_2 x_0 + E_2 \\ x_0 (S_1 - S_2) &= E_2 - E_1 \\ x_0 &= \frac{E_2 - E_1}{S_1 - S_2} \end{aligned} \right\} \quad (14)$$

By substituting in these equations the values of x_0 there are obtained the values of y_0 .

These formulas can be used for determining the values of x_0 and y_0 without graphic construction.

If the straight lines expressing the total cost of treatment of the lot of elements do not intersect each other,

then on one of the machines, for which the straight line is lower, the cost of treatment will be lower for any number of elements in the lot.

It should be noted that the comparison of the economy of the production of elements on two (or more) machines on the basis of the cost of treatment is only valid if the form of the blank is the same for both machines. However, if different forms of blanks must be employed for the compared machines, then this comparison must occur on the basis of the production cost of the element (sum of the cost of the material, the basic wage for the productive work, and the shop overhead) at production on each of the compared machines.

As a criterion for the selection of the machine for the planned technological process there may sometimes be taken the period during which there is repaid the cost of the more expensive of two compared machines.

If the more expensive machine is also more productive and the cost of treatment on it is lower than on the other, less expensive machine, then the period during which the cost of the more expensive machine is repaid can be calculated according to the formula

$$H = \frac{S_1 - S_2}{(c_2 - c_1) N} \quad (15)$$

where H is the number of years during which the cost of the more expensive machine is repaid;

S_1 is the cost of the more expensive machine;

S_2 is the cost of the second machine;

c_1 is the cost of treatment of the element on the first machine;

c_2 is the cost of treatment of the element on the second machine;

N is the number of elements or products of the yearly production program.

At the selection of the equipment there must be selected sufficiently modern machines and machines of a particular type.

The principal and fundamental problem of modern machine construction is the attainment of the shortest treating time at the lowest cost and the greatest precision of treatment.

In view of the direction of the development of modern machine construction and the endeavour to obtain the most economical effect at the production of products, it is necessary at the planning to carry out a comparison of the several variants of the treatment of the elements on the various types of machines, and, as a result of the analysis of the several variants, to adopt the most suitable and effective.

At the planning of the technological process of the treatment of the elements, when the plan is formulated and the method of treatment of the elements is selected, simultaneously with the selection of the types and sizes of the machines there must also be established the particular accessories necessary for the performance of the intended operations on the given machines.

If there are required normal accessories consisting of appurtenances of the machine (vices, supports, squares, etc.) there should be indicated only their names, but if for a given operation there is required a special accessory there is stipulated "special accessory" and furnished a drawing of its construction.

In the stage of the technical planning the technologist usually furnishes only the diagram or general form of the necessary accessory or only indicates on the technological chart the kind of accessory and its principle of operation.

For the formulation of the working technological process there is constructed a model of the accessory and prepared the working drawings thereof. This is usually done by the designing staff of the makers of the accessory.

At the treatment of the elements with employment of the accessory there is eliminated the necessity of marking their dimensions before the treatment; in this way there are eliminated expensive and tedious operations, at which there are introduced errors in the dimensions, depending on the individual quality of the marker.

The employment of accessories assures greater precision of treatment, and equally for all of the elements, which in turn assures a greater degree of interchangeability.

Further, the employment of accessories facilitates and hastens the placement and fastening of the elements in the machine, which considerably shortens the auxiliary time, and is sometimes considerable, and sometimes greater than the basic time. The employment of accessories also enables the treatment to

be carried at more rapid cutting conditions and the employment of workers with lower qualifications.

For obtaining the necessary precision of the dimensions of the elements produced with the help of accessories the construction of the accessories themselves must be more precise than is necessary for the treatment of the elements and in such a way that the error at the treatment of the elements is not increased because of imprecisions of individual parts of the accessories. In this connection it is necessary in stipulating the permissible deviations in the dimensions of the fundamental elements of the accessory to stipulate permissible deviations in these dimensions 2 times smaller than the permissible deviations for the treatment of the elements. In this way the necessary precision of the treatment of the elements will be assured.

In individual and small-series production there are widely employed treatments without accessories or with accessories of universal type, which are usually appurtenances of the machines (dividing universal heads, rotary tables, etc.).

In large-series and mass production the employment of accessories is obligatory: in each individual case there are only decided the questions of the construction of the accessories of the number of elements to be treated with them simultaneously.

The construction of the accessory must be such that the time for the placement and fastening of the elements is minimal; at this the fastening of the element must be sufficiently strong and reliable, with taking into account of the character of the operation and the stress of the cutting.

Before proceeding with the designing of the accessory it is necessary to clarify the economic feasibility of its employment, which can be done in the following manner.

The cost of treatment S_1 of one element without the accessory is

$$S_1 = P_1 + R_1 \quad (16)$$

where P_1 is the basic wage of the production worker in the treatment of one part without the accessory;

R_1 is the shop overhead in the treatment of one element without the accessory.

The cost of treatment S of the same element with use of the accessory is as follows:

$$S_2 = P_2 + R_2 + \frac{B}{H N} \quad (17)$$

where P_2 is the basic wage of the production worker in the treatment of the same element with the accessory;

R_2 is the shop overhead at the treatment of the same element with the accessory;

B is the cost of the accessory;

H is the useful life of the accessory in years;

N is the number of elements treated per annum.

Subtraction of equation (17) from equation (16) gives

$$S_1 - S_2 = (P_1 + R_1) - (P_2 + R_2 + \frac{B}{H N}) \quad (18)$$

If the value of $S_1 - S_2$ is positive it means that the cost of treatment without the accessory is greater than the cost of treatment with employment of the accessory, and in this case the employment of the accessory is advantageous; in the opposite case the employment of the accessory is economically

infeasible.

In the same way there should also be verified the economic feasibility of production of the accessory of the new design when a corresponding old accessory already exists. In this case formula (17) must be written for the employment of the old and the new accessory.

According to formula (17) the cost of treatment of the element with employment of the old accessory is

$$S_2 = P_2 + R_2 + \frac{B}{HN}$$

the cost of treatment of the detail with the new accessory is

$$S_3 = P_3 + R_3 + \frac{B_1}{HN}$$

If $S_2 - S_3$ is greater than 0, then the production of the new accessory is economically feasible.

This calculation is valid if the old accessory is amortized completely; if however, the old accessory is not amortized completely, then the remaining part of its cost must be covered by the economy obtained from the employment of the new accessory; if at this the remaining nonamortized part of the cost of the old accessory is denoted K, then there must be observed the inequality

$$K < (S_2 - S_3) NH$$

(19)

Simultaneously with the selection of the machine and the accessories there must be stipulated for each of the operations the necessary cutting tool for attaining the greatest productivity with the required precision and finish, with a brief characterization thereof: the name and size of the tool, the material from which the tool is made, its mark and standard number (at the adoption of a standard tool), for example, "milling-cutter cylindrical with

diameter 75 x 50 according to GOST 3752-47 of highspeed steel R9^W.

If for the given operation there is required a special tool, then instead of the stipulation of the standard number there is noted: "special tool"; in this case there must be furnished a drawing of its construction.

The employment of any type of tool depends on the following principal factors: type of machine, method of treatment, material of element to be treated, its dimensions and construction, necessary precision and finish of treatment, character of production (individual, series, mass).

Since the cost of the tool enters into the cost of the treatment (according to the form of the overhead), it is necessary at the selection of the tool to endeavor to attain in correspondence with the employed method of treatment complete utilization of its cutting characteristics.

The selection of the material of the cutting part of the tool is of great importance for increasing the productivity and decreasing the cost of the treatment.

For the production of the cutting parts of tools there are employed:

(a) hard alloys (GOST 3882-47), (b) tool steels, carbon (GOST V-1435-42), alloyed (OST 14958-39) and highspeed (GOST 5952-51) and (c) mineral-ceramic alloys.

The selection of the material of the cutting tool depends on the employed method of treatment, the kind of treated material and the conditions of the work (further details on these questions will be found in the course "Metal-Cutting Tools").

At the formulation of technological processes there must be stipulated, besides the cutting tools, also the measuring implements necessary for the measurement of the elements in the process of their production, with a brief characterization: name, type, size.

At individual production there are employed general-purpose measuring-

implements, that is, such with which various dimensions can be verified, for example, rulers, outside calipers, trammels, micrometers, inside calipers, depth meters, inside micrometers, measuring devices, etc. In series and mass production there are employed strict measuring implements - calipers and gauges, as well as measuring accessories and devices.

The measuring implement is selected in dependence on the form of the surface to be measured and the required precision.

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E. Determination of dimensions of surfaces to be treated

For each of the transitions entering into the operations carried out on the given machine there are stipulated the dimensions of the surfaces to be treated - diameter and length or width and length, according to which there is calculated the time necessary for executing the treatment at the given transition. Further, according to the diameter and the number of revolutions there can be calculated the cutting speed. As the diameter of the surface to be treated there is stipulated the maximal diameter, that is, the one obtained after the preceding treatment (blank or preceding transition), at which there was established the tolerance for the next treatment, for example: diameter of finished shaft 60 mm, diameter of blank shaft 65 mm. If for the final finish facing of the shaft there is left a tolerance of 1 mm, then the diameter after the rough facing must be equal to 61 mm. At the calculation of the time for the rough treatment the calculated diameter will be 65 mm, and, for the final finishing, 61 mm. The number of revolutions of the element at the stipulated cutting speed is determined according to these calculated diameters.

At a strictly definite number of working strokes at the stipulated cutting speed that dimension of the length is indicated in the direction of the working motion and the dimension of the width in the direction of the feed.

The calculated dimension of the length is composed of the dimension of the length of the surface to be treated and the dimension referred to the downstroke and the outstroke (cutting-in and running-across) of the tool.

The calculated dimension of the width of the surface to be treated is composed of the final dimension of the width of the finished element and the dimension of the tolerance for the width (if there is one).

Further, at the necessity of taking test cuttings it is necessary to add to the indicated dimension the total length traversed at the taking of the test cuttings.

Accordingly, the calculated length of the treatment can be expressed as follows:

$$l = l_o + l_{vr.n} + l_{str} \quad (20)$$

or

$$l = l_{ch} + l_{pr} + l_{vr.n} + l_{str} \quad (21)$$

and

$$l_o = l_{ch} + l_{pr}$$

where l_o is the length of the surface to be treated in mm;

l_{ch} is the final length after the treatment in mm;

l_{pr} is the tolerance for the length in mm (if there is one);

$l_{vr.n}$ are the lengths of cutting-in and running-across (downstroke and outstroke) of the tool in mm;

l_{str} is the total length of the traverse at the taking of the test cuttings in mm.

The determination of the lengths of the cutting-in and running across is described later at the discussion of the question of the calculation of the basic technological time.

The total length of the traversal at the taking of test cuttings is taken in dependence on the dimensions of the surface to be treated in the limits of 6-8 mm, and sometimes of 10 mm.

F. Selection of the cutting conditions of the metal

A detailed account will be found in the course "Uchenie o rezanii metallov" (Textbook on the cutting metals). Here we give only a brief general account applied to the planning of mechanical shops.

One of the important factors of the technological process is that of the cutting conditions established for the treatment of the elements.

The cutting system of a metal includes the following fundamental components: the cutting speed denoted or the number of revolutions of the spindle of the

machine denoted n rpm, the feed denoted s , and the depth of cutting denoted t .

The starting data for the selection of the cutting system are:

(1) The data on the elements to be treated (working drawing and technical conditions): (a) Kind of material and its characterization (mark, state, mechanical characteristics); (b) form, dimensions and permissible deviation in the treatment; (c) permissible deviation from the geometric form (ovality, conicity, bounding, permissible error of mutual coordination of individual surfaces; (d) required finish (microgeometry) of treated surface; (e) requirements as to the state of the surface layer (permissible strengthening, tempering);

(2) Information on blank (drawing and technical conditions); (a) kind of blank; (b) magnitudes and character of distribution of tolerances; (c) state of surface layer (presence of crust, scale, solidification);

(3) Certificate of machine.

The components of the cutting system are selected in such a way as to attain the greatest productivity of the work at lowest cost of the given technological operation.

The stated conditions apply to working with tools of rational design (properly selected material for the tool, optimum geometry, necessary strength, rigidity, stability to vibration, etc.) and, if the machine is not limited to full utilization, the cutting characteristics of the tool. The cutting system is established on the basis of the particularities of the element and the characterization of the cutting tool and of the machine.

The selection of the components of the cutting system is inseparable from the selection of the parameters of the tool.

For attaining maximum productivity it is necessary to take measures for increasing the utilizability of the machine. Among such measures are:

(1) Increasing the number of revolutions by changing pulleys, cogwheels, motor drives;

(2) Increasing the power and traction of the equipment by changing motors, use of belt tighteners, etc;

(3) Increasing the strength of the limiting (weakest) links of the mechanism;

(4) Increasing the rigidity of the element being treated and the security of its fastening by employment of special clamping devices and accessories;

(5) Improving the working characteristics of the cutting tool, increasing its strength and the security of its fastening, etc.

The selection of the magnitudes of the cutting components and of the parameters of the machining tools is done in the following order:

1. The depth of cutting is selected as a function of the tolerance and the number of passes.

The tolerances for the treatment are worked out for the rough, finish and individual treatments.

The value of the tolerance is determined in dependence on the results of the preceding treatment: the value of the defective layer (strengthening, tempering, annealing, etc.), the microgeometry of the surface, the error in the form of the element, the error in the adjustment of the element for the given operation and the permissible deviation at the execution of the preceding operation.

An attempt must be made to decrease the number of passes.

The tolerance for the rough treatment is usually taken for one-two passes.

The number of cleaning and finishing passes is selected in dependence on the required precision of treatment, the cleanness of the surface and the quality of the surface layer of the element.

2. In selecting the cutting tool, the following values are established: its type, dimensions, material and optimum geometry in dependence on: (a) the form of the surface to be treated; (b) the character of the treatment; (c) the material of the cutting part of the tool; (d) the rigidity and vibro-stability of the system.

3. The feed is determined as a function of: (a) the shape of the element and of its treated surface, the rigidity, strength and resistance to vibration, the state of the surface layer, the microgeometry of the surface; (c) characteristics of the machine (strength of mechanisms, feed, speed, etc., rigidity, resistance to vibration, and kinematics).

We adopt the greatest feed permitted by the above-numerated limiting factors. The actual rate of feed to be used, according to the certificate of the machine, comes close to the calculated feed.

The feed is

$$s = \frac{q}{t}$$

where s is the feed in mm;

q is the section of the cutting in mm²;

t is the depth of cut in mm.

4. The selection of the fatigue limit cutting tool depends on the type and size of the tool, the characteristics of the element to be treated and the conditions of the work. The average values for the fatigue limit are compiled in corresponding norms.

5. The cutting speed and the number of revolutions are determined as a function of the preselected factors according to the formula

$$v_T = \frac{C_v}{t^{x_v} s^{y_v}} \quad (22)$$

where v_T is the cutting speed at the selected yield point of the cutting tool, equal to T min;

t is the depth of cutting in mm;

s is the feed in mm/revolution;

x_v and y_v are indices of degree of depth and feed;

C_v is a constant value depending on a number of factors: material of the tool, material to be treated, type of treatment (external machining, boring, cutting-out, etc.), character of treatment (roughing, finishing), presence of cooling, etc.

In selecting the second period of endurance T_1 , differing from T , the cutting speed v_{T1} , corresponding to the period of endurance T_1 , must be recalculated according to the equation

$$v_{T1} = v \left(\frac{T}{T_1} \right)^m \quad (23)$$

where m is the index of relative endurance.

The value of m at the edge of the cutter varies as a function of the treated material, the material of the cutting part, the type of cutter, and the working conditions, between 0.1 and 0.3.

The cutting speed v is determined according to the formula

$$v = \frac{\pi d s n}{1000} \text{ m/min} \quad (24)$$

where d is the diameter of the treated element in mm;

n is the number of revolutions of the spindle per minute.

According to the selected cutting speed the number of revolutions is determined according to the formula

$$n = \frac{v 1000}{\pi d} \quad (25)$$

After determining the rated number of revolutions the actual number of revolution is selected according to the certificate of the machine, close to the rated rpm; in the absence of a certificate only the rated number of revolutions is determined in this case, it is necessary to take into account the progress of the box at the speed of the machine and not to change the number of revolutions at small changes in the diameter of the treatment.

The basic technological time t_0 is determined according to the formula

$$t_0 = \frac{l}{s n} \quad (26)$$

where l is the calculated length of the treated surface in mm;

n is the feed of the rotating machine spindle per minute;

s is the feed in mm/revolution.

To reach the least expenditure of time in the treatment the values of n and s for the given machine must be such as to give the greatest possible product

of ns.

However, it must be borne in mind that the smallest machine time does not always correspond to the smallest cost of treatment of the element, because an increase in the working conditions brings about an increase in the consumption of tools, the expenditure of time for retooling the equipment, changing tools, and other increased expenditures.

On this basis the length of the machine time must be determined in correspondence with the optimal working conditions of the equipment, at which there is attained the greatest productivity of the work at the least cost of the operation.

6. Determination of cutting force and torque.

The values of the cutting force in kilograms are determined according to the formulas:

vertical cutting force

$$P_z = C_{pz} \cdot t^{x_{pz}} \cdot s^{y_{pz}}$$

radial cutting force

$$P_y = C_{py} \cdot t^{x_{py}} \cdot s^{y_{py}}$$

axial cutting force

$$P_x = C_{px} \cdot t^{x_{px}} \cdot s^{y_{px}}$$

(27)

where C_{pz} , C_{py} and C_{px} are coefficients depending on the treated material;

t is the cutting depth in mm;

s is the feed per revolution in mm;

x_{pz} , x_{py} and x_{px} are indices of degree at the cutting depth;

y_{pz} , y_{py} and y_{px} are indices of degree at the feed.

The torque M_{kr} is determined according to the formula

$$M_{kr} = P_z \cdot \frac{d}{2} \text{ kgmm}$$

(28)

where d is the diameter of the element in mm.

7. Determination of the required power of the machine.

The effective power referred to the cutter is

$$N_e = \frac{P_z v}{60 \times 102} \text{ kw} \quad (29)$$

where P_z is the vertical component of the cutting force in kg;
 v is the cutting speed in meters/minute.

The necessary power of the drive of the machine will be

$$N_e = \frac{N_e}{\eta} = \frac{P_z v}{60 \times 102 \eta} \quad (30)$$

where η is the efficiency of the machine.

The value of the efficiency η is taken according to the certificate of the machine (on the average $\eta = 0.80-0.85$).

Calculating the value of N_e according to eq. (30), it is compared with the power of the selected machine; dividing the first value by the second will yield the efficiency of the machine relative to the power, i.e.,

$$\eta_m = \frac{N_e}{N_{st}} \quad (31)$$

where η_m is the efficiency of the machine relative to the power;

N_e is the required power of the machine in hp or kw;

N_{st} is the power of the adopted machine in hp or kw.

If the power of the selected machine is smaller than that required by the calculation the cutting speed rather than the feed must be decreased. The values of the constants of the coefficients and indices of degree in the formulas for the determination of the speed and force of cutting, as well as the corrected coefficients for the speed and force of cutting at unchanged treating conditions, will be found in the norms for the establishment of cutting conditions (Norms of the Scientific-Research Bureau of Technical Standards of the Ministry of Machine-Tool Building or the Ministry of Machine Building). These norms contain prepared Tables and graphs for determining the cutting factors, compiled on the basis of mathematical formulas, which are generally used in the practice of formulating technological processes, as well as in industrial practice. In each particular case, however, it is necessary to confirm by calculation the selected values of the cutting factors.

For other forms of treatment (drilling, milling, grinding, tooth-cutting, threading) the cutting procedure is established in the following order.

For work on the drill press first the feed is determined and then, according to the selected feed, the diameter of the drill, after which the cutting speed is calculated as a function of the treated material. After establishment of the feed for the given drill diameter, the torque is calculated. Further, according to the torque and the number of revolutions (obtained according to the cutting speed) the power of the drill is determined. The calculated torque on the drill must be compared with the torque according to the certificate of the machine for the number of revolutions at which the drilling is done.

The establishment of the cutting procedure for cylindrical, tail-form and disk-form milling cutters consists in a determination, at the given cutting depth, of the feed (in mm of the tooth), the minute feed (in mm/min), the cutting speed (in meters/min), the number of revolutions of the milling cutter per minute, the tangential force (in kg) and the effective power (in kw); for end milling the feed of the tooth, the minute feed, the cutting speed, the number of revolutions and the effective power are determined.

In establishing the cutting procedure for grinding, the following data are defined: the rotary speed of the grinding wheel (in meters/min) as a function of the treated material, the rotary speed of the element (in meters/min), the longitudinal feed of the wheel (for the usual method of grinding, in shares of the wheel; for deep grinding, in mm per revolution of the element), the transverse feed - cutting depth (in mm when operating the wheel with longitudinal feed, in mm per revolution of the element, when grinding point-blank), the number of revolutions of the table and the depth of grinding per revolution (when grinding on a machine of the vertical type), the travel speed of the table (in meters/min, when grinding on a machine of the longitudinal type).

For cutting cylindrical cogwheels on milling and tooth-cutting machines the speed is determined (in meters/min); the cutting speed is taken as a constant value for the given treated material.

For cutting cylindrical cogwheels with straight and spiral teeth on a tooth-cutting machine, operating with worm-type milling cutters, the feed (in mm) per revolution of the treated element, the cutting speed (in meters/min) and the effective power (in kw) are determined; for cutting wormwheels on the same machine by the method of radial feed, the radial feed (in mm) per revolution of the treated element is determined; the cutting speed is taken as a constant value for the given material.

For cutting cylindrical cogwheels with gear-shaper cutters on tooth-cutting machines, operating on the generating principle, it is necessary to determine the peripheral speed (in mm) relative to the initial circumference of the wheel to be cut per double stroke of the gear shaper cutter, the cutting speed and the number of double strokes.

For cutting cogwheels of racks on gear shapers the number of cuts per tooth of the wheel, the cutting speed, and the number of double strokes per minute are determined.

For cutting bevel gears on gear shapers of one type, the feed (in mm) per double stroke of the slide and the number of double strokes of the slide per minute, are determined; for cutting of bevel gears on machines of a second type, the feed (in mm) per revolution of the wheel being cut and the number of double strokes of the slider per minute are defined; for cutting bevel gears on machines of a third type, the generating feed (in mm/min) and the number of double strokes of the slide are calculated. The cutting speed for all of these machines is taken as a constant value for the given treated material.

For cutting threads with cutters and racks the cutting speed (in meters/min) is determined; the feed (in mm per revolution) is the pitch of the thread

being cut (in mm); the number of revolutions of the element to be cut is determined from the formula of the cutting speed. For cutting threads on thread-milling machines with disk and group milling cutters the cutting speed (in meters/min) and the feed in mm per minute are determined with disk milling cutter and in mm of tooth with group milling cutters.

G. Determination of Time norms of Treatments

It has been seen above that one of the fundamental factors of a technological process is the time necessary for treatment of the element. It is the time norm for the wage for the work, for the calculation of the cost of the elements and products, and for the calculation of the necessary number of machines and workers in the shop.

In establishing the time norms the following conditions must be assured:

- (1) The work must be performed by workers with suitable qualifications;
- (2) The most effective accessories and tools for the given work must be employed;
- (3) The optimum cutting procedure must be established on the basis of the possibility of rational employment of simultaneous treatment of several elements, simultaneous operation of several tools, and, where possible, simultaneous tending of several machines by one worker;
- (4) The treatment tolerance must be standard for the given works. The machines must be in good condition and the quality of the tools must be normal;
- (5) The manual manipulations which can be carried out simultaneously with the operation of the machine, that is, occurring within the machine time must be included;
- (6) No manipulations for correcting treated elements or for refabricating them must be included;
- (7) The organizations of the working places must be supplied with the

necessary materials, tools, accessories, drawings, clothing, and be relieved of nonproductive work by auxiliary workers;

(8) The sharpening of the tools must be centralized in a sharpening department of the shop with special workers (centralized sharpening is further discussed below). Tools are changed at fixed intervals of time or at the request of the machinist; sharpened tools are delivered to the working place ready to use;

(9) The time norm must not contain loss of time due to organizational failures such as: interruption of current supply, delay in delivery of materials, accessories, tools, delay in transport means, workclothes or assignment of work, defective electric motors, etc.; in other words, there must be assured uninterrupted and timely servicing of the working place with everything necessary for working without interruption;

(10) The time norm is established on the basis of normal working conditions, and any loss of time, whether or not depending on the worker, is not included in it.

The norm of the piece time is expressed by the following formula:

$$t_{\text{sht}} = t_0 + t_v + t_{\text{ob}} + t_f \quad (32)$$

where t_{sht} is the norm of the piece time in min;

t_0 is the basic (technological) time in min;

t_v is the auxiliary time in min;

t_{ob} is the time of servicing the working place in min;

t_f is the time for the physical requirements in min.

Since, however, the time for servicing the working place is composed of the time for technical servicing and the time for organizational servicing, the general formula (32) of the norm of the piece time must be written in the following form:

$$t_{\text{sht}} = t_0 + t_v + t_{\text{t.o}} + t_{\text{o.ob}} + t_f \quad (33)$$

where $t_{\text{t.o}}$ is the time of technical servicing of the working place in min;

$t_{o.ob}$ is the time of organizational servicing of the working place in min.

The operating time is $t_{op} = t_o + t_v$ (34)

The time norm for the treatment of the given lot of elements T_p is expressed by

$$T_n = t_{sht} n + T_{p.z} \text{ min} \quad (35)$$

where n is the number of pieces in the lot; $T_{p.z}$ is the readying-fastening time for the whole lot in min.

The norm of the total calculated time per piece t or piece-calculated time is determined according to the formula

$$t_k = \frac{T_p}{n} = t_{sht} + \frac{T_{p.z}}{n} \quad (36)$$

The time of the technical servicing of the working place is calculated in a percentage of the basic (technological) time, and the time of the organizational servicing in a percentage of the operative time.

Then, the general formula for the norm of the piece time (33) is written as:

$$t_{sht} = t_o + t_v + t_o \cdot \frac{\alpha}{100} + (t_o + t_v) \frac{\beta}{100} + (t_o + t_v) \frac{\gamma}{100} \quad (37)$$

or

$$t_{sht} = t_o + t_v + t_o \cdot \frac{\alpha}{100} + (t_o + t_v) \frac{\beta + \gamma}{100} \quad (38)$$

where α is the percentage of the basic (technological) time expressing the time of the technical servicing of the working place; β is the percentage of the operative time expressing the time of the organizational servicing of the working place; γ is the percentage of the operative time expressing the time for the physical requirements.

For simplifying the calculation of the norm of the piece time, the time of the technical servicing may be expressed in percentage relative to the operative (but not the basic) time, for which it is necessary to recalculate the time of the technical servicing, taken in a percentage to the basic technological time, and the percentual ratio to the operative time (that is, the sum of the basic and auxiliary times); for this purpose it is necessary to know the ratio between the basic and the auxiliary time.

In this case the general formula of the norm of the piece time (37) will have the form

$$t_{shl} = t_o + t_v + (t_o + t_v) \cdot \frac{\alpha'}{100} + (t_o + t_v) \cdot \frac{\beta}{100} + (t_o + t_v) \cdot \frac{\gamma}{100} \quad (39)$$

or

$$t_{shl} = (t_o + t_v) \cdot 1 + \frac{\alpha' + \beta + \gamma}{100} \quad (40)$$

or

$$t_{shl} = t_{op} \cdot 1 + \frac{\alpha' + \beta + \gamma}{100} \quad (41)$$

where α' is the percentage of the operative time expressing the time of the technical servicing of the working place.

Formulas (37) and (39) are fundamental for the calculation of the norms of the piece time.

On machine work the worker is given the time norm for the treatment of one element or the norm of the output in the shift.

The norm out of the output in the shift N_{sm} in pieces is expressed by the following formula:

$$N_{sm} = \frac{T_{sm}}{t_{shl}} \quad (42)$$

where T_{sm} is the duration of the working shift in min (480 min).

If several elements are produced simultaneously from one blank, the time per element is determined by dividing the sum of the treating times of the blank ((according to formula (37) or (39)) by the number of simultaneously treated elements obtained from one blank.

Methods of determination of time norms

The determination of the technical time norm for the treatment of an element is carried out on the basis of an analysis of the work and calculation according to the constituent parts of the individual operations. This method is called the analytical-calculation method.

In dependence on the form and character of the production the calculation of the technical norm occurs in different ways: for mass production according to the

individual manipulations, for series production according to the combined group of manipulations, for individual and small-series production by employment of a norm established for a typical technological manipulation or operation.

The time norm for the individual manipulation or group of manipulations of manual work is determined according to the corresponding standard times formulated on the basis of the given time study, at whose execution the rational sequence of manipulations of the work necessary for each of the manipulations and its proper execution, the possibility of performing the individual manipulations in the machine time period (within the machine time) were established.

The time of the machine work (basic technological time) is determined by theoretical calculation according to the formula derived on the basis of the kinematic scheme of the machine, and also in relation to the cutting procedure.

The time norm for all of the operations is obtained as the sum of the elementary times for the manual and machine work corresponding to formulas (33) and (36).

In the planning of mechanical shops for series production, when it is necessary to standardize a large number of elements, the determination of time expenditure for the treatment may be determined by the method of comparison-graphic or analytical. This method is very convenient for determining the treating time of elements of the same or similar construction made of one and the same material, requiring similar treatment, and differing from each other only in their dimensions. In this case the time norms for similar elements of three sizes: largest, smallest and medium-sized are calculated.

The basic (technological time) time is calculated theoretically (according to formula), while the remaining components of the time (auxiliary, for servicing the working area and for physical requirements) are determined according to standards.

According to the time norms obtained for the treatment of the three elements (largest, smallest and medium-sized), a graph is constructed on whose ordinate the calculated time norms of the treatment of the elements, and on whose abscissa their

size or weight are laid out. The time for the treatment of the medium-sized element is taken directly from the graph. The graph is constructed for an individual operation or for the complete treatment of the element. This method gives a considerable saving in the time expended on the standardization of elements.

Examples of graphs representing the dependence of the treating time on the size or weight of the element are presented in Fig.39.

Character analysis of the curves constructed for the treating times of the several elements depending on their size or weight shows that these curves approach a semicubical parabola.

On this basis it is permissible for the treating time of two comparable, geometrically similar elements to depend on their weight according to the law of semicubical parabolas. Therefore, knowing the weights of the details and the treating time of one of them, the treating time of the other details can be determined from the following equality:

$$\frac{t_x}{t_1} = \sqrt[3]{\left(\frac{g_x}{g_1}\right)^2} \quad (43)$$

where t_x is the time (unknown) for treatment of the one element;

t_1 is the time (known) for treatment of the other element;

g_x is the weight of the element whose treatment is denoted by t (unknown value);

g_1 is the weight of the element whose treatment is denoted by t (known value).

Expressing the weights of the element by the volumes (respectively V_x and V_1), multiplied by the specific gravity γ (elements of one and the same material), gives:

$$\frac{t_x}{t_1} = \sqrt[3]{\left(\frac{g_x}{g_1}\right)^2} = \sqrt[3]{\left(\frac{V_x \gamma}{V_1 \gamma}\right)^2} = \sqrt[3]{\left(\frac{V_x}{V_1}\right)^2} \quad (44)$$

The righthand part of the equation represents substantially the ratio of the surfaces, because the cube root of the volume (that is, of the cubic dimension) gives a dimension of the first degree, which is in its turn squared, and a quadratic dimen-

sion determines a surface.

From this it follows that the ratio of the treating times is equal to the ratio of the surfaces of the elements. Because the elements are geometrically similar, the

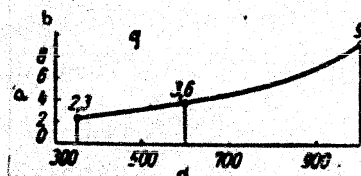
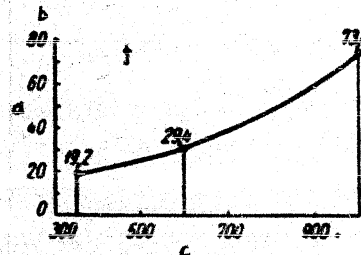
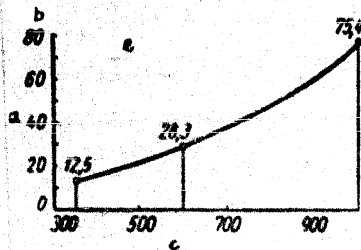


Fig.39 Examples of Graphs for Determining the Treating Time of Elements

a) time; b) minutes; c) diameter of flange; d) diameter of blind flange; e) boring flange; f) drilling hole in flange; g) facing blind flange

ratio of the common surfaces of the elements will equal the ratio of the treated surfaces, and hence the ratio of the treating times will equal the ratio of the treated surfaces, that is, the treating times of two similar elements are proportional to their surfaces, and also correspond to the actuality.

As is seen, instead of calculating the ratio of the surfaces, which is difficult, this ratio can more easily be determined according to the weights of the elements.

It should be noted that the results obtained with this formula are sufficiently precise for practical purposes only with comparable elements, made of the same material, having geometrically similar constructions, and differing from each other only in their dimensions. In the case of a small constructional difference between the elements there will be some error in the determination of the treating time.

Determination by the comparison method of the time norms for mechanical work may occur according to the relation

$$\frac{t_x}{t_1} = \frac{S_x}{S_1}$$

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that is, taking the time for the mechanical treatment of two similar elements as directly proportional to their weights.

The calculation of the time components occurs in the following order:

- (1) The readying-closing time for the whole lot is determined;
- (2) The basic technological time is calculated;
- (3) The auxiliary time is determined;
- (4) The time for the technical and organizational servicing and for natural needs is calculated.

According to formula (40) the last time component (point 4) may be taken as the sum of the percentual needs referred to the operative time.

Determination of the readying-closing time

The duration for the individual readying and closing actions at the execution of the treating operations are derived from the norms compiled from the experimental data as based on the study and generalization of experiments on the work of innovator pacemakers and guided by data on scientific research and industrial operations (Standards of the Scientific Research Bureau of Technical Standardization of the Ministry of Machine Tool Building and the Ministry of Machine Building of the USSR). The magnitude of the readying-closing time is influenced by the work organization of the shop, the type of treatment of the elements, the complexity of the machines and accessories, the method of fastening the elements, etc. It must be sought to make this nonproductive time as short as possible; its shortening gives the possibility of considerably improving the utilization of the equipment, which stands idle and nonproductive during the execution of the readying and closing manipulations. The machinist must be relieved of this work, which can be done by auxiliary workers. In mass production the adjustment of the machines, tools and accessories, as well as the readying of the working area, is done by special fixers and auxiliary workers before the beginning of the next shift. In series production the adjustment of the machines, tools and accessories and the readying of the working area is also carried

out by special fixers and auxiliary workers, but a somewhat greater part of the readying-closing time also belongs to the machinist.

In individual and small-series production the adjustment of the machines, tools and accessories is done by the machinist himself, and the time expended by him on this work reaches a considerable amount.

When determining the readying-closing time norm, provisions must be made for organization of the work so that the materials, tools, accessories, drawings and clothes are delivered to the working place.

The readying-closing time norms are composed in such a way that the times for carrying out the components of the work are referred to the readying and closing manipulations in the execution of machine operations, comprising two magnitudes: (a) the time for the adjustment of the machine, accessories and tools; and (b) the time for the supplementary manipulations.

In work on rotary machines the time for the test treatment of the element, which is added in the form of a third component to the magnitudes indicated in points a and b, is included in the norm.

The magnitude of the readying-closing time depends on the type and size of the machine, the method of adjustment, the accessories used, the number of cutting tools in the tooling, and also on the technological similarity of the elements of the several lots assigned to the same machine.

The time for the test treatment of the element depends on the number of cutting tools, the adjustment to the respective dimensions, and the magnitude of the operative time for the treatment of the element.

It should be borne in mind that a complete readying of the working area gives a longer working time without interruption and without supplementary readjustment.

Calculation of the basic (technological) time

The basic technological time, as stated above, is calculated theoretically. The components of the cutting are taken according to calculation, or, as customary in

planning, according to tables, and, on the basis of the above presented considerations, the time necessary for the machine treatment is calculated. For this purpose a fundamental formula which is valid for all forms of treatment is used. The form of this formula varies depending on the particular form of treatment.

The fundamental formula has the following appearance:

$$t_0 = \frac{li}{ns} \text{ min} \quad (45)$$

where t_0 is the basic technological time;

- 1 is the calculated length of treatment in the direction of feed in mm (compare formula (21));
- n is the number of rotations of the spindle per minute for machines with rotary movement, or the number of double strokes per minute for machines with rectilinear movement;
- s is the feed per revolution or per double stroke of the main movement (cutting movement) in mm;
- i is the number of passes.

The basic (technological) time for lathe work at a given number of revolutions and feed is determined according to formula (45) which remains unchanged for this form of work. In this case s will be the feed of the cutter in mm per revolution of the spindle, n the number of revolutions per minute, l the calculated length of cylindrical facing or boring in the direction of feed in mm (according to formula (20)).

From the formula

$$v = \frac{\pi d n}{1000} \text{ m/min}$$

the number of rotations n per minute

$$n = \frac{v \cdot 1000}{\pi d}$$

Substitution of the value of n in formula (45) gives

$$t_o = \frac{\pi d l i}{v_s \cdot 1000} \quad (46)$$

For end facing a shaft and cutting off

$$l = \frac{d}{2} \text{ mm}$$

In this case the fundamental formula (45) will have the form

$$t_o = \frac{d i}{2 n s} \text{ min} \quad (47)$$

For end facing a hollow cylinder

$$l = \frac{d_n - d_{vn}}{2} \text{ mm} \quad (48)$$

where d_n is the outside;

d_{vn} is the inside diameter of the cylinder.

Substitution of the value of l in formula (45) gives for end facing of a hollow cylindrical body the formula of the basic time:

$$t_o = \frac{(d_n - d_{vn}) i}{2 n s} \text{ min} \quad (49)$$

For grooving t_o will be expressed by the same formula. In this case d_n is the diameter before and d_{vn} the diameter after the grooving.

When facing several surfaces with several cutters simultaneously, the value of l in formula (45) is taken for the cutter having the longest stroke. The working time of the other cutters with a shorter stroke is included in the working time of the cutter with the longest stroke.

The basic time for planing work on a longitudinal planing machine is also determined according to formula (45), at which the value of l equals the length of treat-

ment in the direction of feed. In a planing machine the feed is transverse to the direction of planing, that is, along the width of the element, therefore in this case l will denote the width of planing, which is composed of the width of the planed surface, the cutting-in and lateral overhang of the cutter. Then formula (45) takes the form

$$t_o = \frac{(b + b_1) i}{ns} \text{ min} \quad (50)$$

where b is the width of the planed surface in mm;

b_1 is the cutting-in and lateral overhang of the cutter in mm;

i is the number of passes;

n is the number of double strokes of the table per minute;

s is the feed of the cutter per double stroke of the table in mm.

The number of double strokes can be determined on the basis of the stroke length

of the table.

The velocity of the working stroke of the table is

$$v_p \cdot x = \frac{L (1 + m) n}{1000} \text{ m/min} \quad (51)$$

where L is the length of stroke of the table equal to the length of the planed surface plus the downstroke and overrun of the cutter in mm;

t is the ratio of the velocity of the working stroke of the table to the velocity of the idle stroke;

n is the number of double strokes per minute.

From formula (51) it follows that the number of double strokes per minute will

be

$$n = \frac{v_p \cdot x \cdot 1000}{L (1 + m)} \quad (52)$$

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Substitution of the value of n from this formula in formula (50) gives

$$t_o = \frac{(b + b_1) L (1 + m) i}{v_p \cdot x \cdot 1000 \text{ s}} \quad (53)$$

The cutting-in in the lateral overhang of the cutter is taken at

$$b_1 = \frac{t}{\tan \varphi} + a \text{ mm} \quad (54)$$

where t is the cutting depth in mm;

φ is the main angle of the cutter in the plane;

$a = 2 \div 5 \text{ mm}$.

The downstrokes and overruns of the cutter in the longitudinal direction entering into the magnitude of L are taken for longitudinal planing machines in the following amounts:

	<u>Overrun of cutter in mm</u>
Planing length L up to 2000	up to 200
Planing length.....2000 - 4000	201 - 300
Planing length.....4000 - 6000	301 - 375
Planing length.....6000 - 10000	376 - 450

The number of double strokes is sometimes, for simplifying the calculation, taken as the average speed of travel of the table (average velocity of working and idle stroke of the table), which is manifested negatively on the precision of the calculation of the basic time. In this case

$$n = \frac{v_{ar} \cdot 1000}{2L} \quad (52a)$$

where v_{ar} is the average speed of travel of the table in mm.

The basic time for cross-cut planing mills can also be determined from eq.(50).

The number of double strokes n and the feed s are determined according to the same formulas as for longitudinal planing machines.

The downstrokes and overruns of the cutter (in the longitudinal direction) entering into the magnitude of L are taken for transverse planing machines in the following amounts:

	Overrun of cutter in mm
At length of stroke of cutter in mm up to 100	35
At length of stroke of cutter in mm of....100 - 200	50
At length of stroke of cutter in mm of....201 - 300	60
At length of stroke of cutter in mm.....above 300	75

The cutting-in and overhang are determined according to formula (54).

The basic time for cylindrical and end milling is determined according to the formula

$$t_0 = \frac{li}{s_m} \text{ min} \quad (55)$$

where l is the calculated length of treatment with the milling-cutter in mm;

i is the number of passes;

s_m is the feed in mm/min.

The calculated length according to formula (20) is

$$l = l_o + l_{vr} + l_{st}$$

The length of cut-in and overrun is

$$l_{ep, n} = l_{vr} + l_n$$

where l_{vr} is the cut-in of the milling-cutter in mm;

l_n is the overrun of the milling-cutter in mm (taken equal to 2-5 mm depending on the diameter of the milling-cutter).

The magnitude of the cut-in of the milling-cutter l_{vr} for cylindrical milling is determined according to Fig.40:

$$l_{vr} = \sqrt{R^2 - (R - t)^2} = \sqrt{R^2 - R^2 + 2Rt - t^2}$$

or

$$l_{vr} = \sqrt{Dt - t^2} = \sqrt{t(D - t)} \text{ mm} \quad (56)$$

where t is the milling depth in mm;

D is the diameter of the milling-cutter in mm.

The magnitude of l_{vr} is usually taken from existing tables.

For end symmetrical milling the magnitude of the cut-in of the milling-cutter

is

$$l_{vr} = 0.5(D - \sqrt{D^2 - b^2}) + \frac{t}{\tan \varphi} \text{ mm} \quad (57)$$

where b is the milling width in mm;

φ is the main angle in the plane.

The magnitude of l_{str} is taken into account when it is necessary to take test cuttings.

The magnitude of the minute feed s_m may be expressed as follows:

$$s_m = s_z z n$$

where s_z is the feed per tooth of the milling-cutter in mm;

z is the number of teeth of the

Fig.40 Scheme of Path of Milling-Cutter at Treatment of Element

milling cutter;

n is the number of revolutions of the milling-cutter per minute.

Accordingly, by substitution in formula (55) of the reported values of l and s_m it can be expressed in two forms:

When test cuttings are not taken

$$t_o = \frac{(l_o + l_{vr} + l_p) i}{s_m} = \frac{(l_o + l_{vr} + l_p) i}{s_m z n} \text{ min} \quad (59)$$

When test cuttings are taken

$$t_o = \frac{(l_o + l_{vr} + l_n + l_{slr}) i}{s_m} = \frac{(l_o + l_{vr} + l_n + l_{slr}) i}{s_m z n} \text{ min} \quad (60)$$

The basic time for milling with circular feed of the table is determined according to the formula

$$t_o = \frac{(l + l_{vr}) i}{s_m} \text{ min} \quad (61)$$

For milling over the whole circumference

$$l = \pi D,$$

where D is the diameter of the milled surface measured over the periphery in mm.

Basic time for milling keyways in one pass:

a) Keyways open on both sides

$$t_o = \frac{l + 0.5D}{s_{m.pr}} \text{ min.} \quad (62)$$

b) Keyways closed on both sides

$$t_o = \frac{k}{s_{m.ver}} + \frac{l - D}{s_{m.pr}} \text{ min.}; \quad (63)$$

c) Keyways closed on one side

$$t_o = \frac{l}{s_{m.pr}} \quad (64)$$

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Basic time for milling of keyways on machines with pendulum feed in several passes:

a) Keyways open on both sides

$$t_o = \frac{(l + 0.5D)}{s_{m \cdot pr}} \cdot i \text{ min;} \quad (65)$$

b) Keyways closed on both sides

$$t_o = \frac{(l - D)}{s_{m \cdot pr}} \cdot i \text{ min} \quad (66)$$

c) Keyways closed on one side

$$t_o = \frac{l}{s_{m \cdot pr}} \cdot i \quad (67)$$

Denotations in formulas (62) - (67):

l is the length of the keyway in mm;

D is the diameter of the milling-cutter in mm;

$s_{m \cdot pr}$ is the longitudinal feed in mm/min;

h is the deepening of the groove by the milling-cutter at each pass in mm;

$s_{m \cdot ver}$ is the vertical feed in mm/min;

i is the number of passes;

$$s_{m \cdot pr} = s_z \cdot z \cdot n \text{ mm}$$

where s_z is the feed per tooth of the milling-cutter in mm;

z is the number of teeth of the milling-cutter;

n is the number of revolutions of the milling-cutter per minute.

The basic time for the treatment of holes with drills, countersinkers, reamers,

broachers and undercutting knives is determined according to the same general formula (45):

$$t_o = \frac{V}{n s} \text{ min}$$

For drilling, countersinking and reaming, the length of passage of the tool is composed of the length of the treated hole and the length of the cut-in of the tool. For these forms of work the formula of the basic time may be expressed in the following manner:

$$t_o = \frac{(l_o + l_{vr})}{sn} \text{ min.} \quad (68)$$

where l_o is the length of the treated hole in mm;

l_{vr} is the length of the cut-in in mm.

The length of time for drilling l_{vr} is determined according to the formula

$$l_{vr} = \frac{D-d}{2} \cdot \text{ctg } \varphi \text{ mm.} \quad (69)$$

where D is the diameter of the drill in mm;

d is the diameter of the crosspiece of the drill in mm;

φ is the main angle in the plane of the drill in degrees.

The cut-in length l at redrilling, countersinking and boring is determined according to the formula

$$l_{vr} = \frac{t}{\text{tg } \varphi} \text{ mm.} \quad (70)$$

where t is the cutting-in depth in mm;

φ is the main angle in the plane.

In Table 5 there are presented the magnitudes of the cut-ins for drills, countersinkers and cylindrical reamers established by calculation with additions to the calculated magnitudes of 2-5 mm from practical experience.

The basic time for cutting threads with profiled cutters or taps is determined according to the formula

$$t_o = \frac{(l + l_p) \text{tg}}{sn} \text{ min.} \quad (71)$$

where l is the length of the thread on the element in mm;
 l_{ox} is the magnitude of the overhang of the cutter in mm;
 s is the feed in mm/revolution (pitch of thread);
 n is the number of revolutions of the element per minute;
 i is the number of passes;
 g is the number of turns of the thread.

Table 5
 Magnitudes of Cut-ins for Drills, Countersinkers
 and Cylindrical Reamers in mm

Name of Tool	Diameter of Tool in mm								
	2-4	5-8	10-14	16-20	22-26	28-32	35-45	50-60	70-100
Drills, spiral	2	3-4	5-6	7-8	9-10	11-12	13-15	17-20	-
Countersinkers, attached and integral	-	-	3	3	5	5	5	6	6
Reamers, cylin- drical	10	15	18	22	26	32	38	45	50

The basic time for cutting threads with disk milling-cutter on thread-milling machines is determined according to the formula:

$$t_o = t_1 + t_2 + t_3 \text{ min.} \quad (72)$$

where t_1 is the cutting time at the first pass in min;

t_2 is the cutting time at the second pass in min;

t_3 is the cutting time at the third pass in min.

The cutting time for each of the passes is determined separately because the cutting depth, the minute feed and the cut-in are different for each of them.

The cutting time for each of the passes t_1 is determined according to the for-

mula

$$t_1 = \frac{(l + l_{ox}) \pi d}{s_1 \cos \alpha \pi} \text{ min.} \quad (73)$$

where l is the length of the thread in mm;

l_{vr} is the magnitude of the cut-in of the disk milling-cutter in mm;

d is the outside diameter of the cut element in mm;

s_t is the pitch of the thread in mm;

α is the angle of inclination of the turns of the thread to the vertical axis of the cut element in degrees;

s_m is the minute feed along the outer circumference of the cut element in mm/min;

g is the number of turns of the thread.

The magnitude of the cut-in of the disk milling-cutter l_{vr} can be determined approximately according to the formula

$$l_{vr} = \sqrt{t(D-t)} \text{ mm.} \quad (74)$$

where t is the depth of the thread in mm;

D is the diameter of the milling-cutter in mm.

The basic time for cutting threads with group milling-cutters on thread-milling machines is determined according to the following formula, derived from formula (73).

For this it is assumed that the element makes one revolution and the coefficient of cutting-in is 1.2, and that the number of passes and the number of turns at cutting with group milling-cutters equals unity.

$$t_o = \frac{1.2\pi d}{s_w} \text{ min.} \quad (75)$$

The basic time for cutting threads by machine tapping in through-holes is determined according to the formula

$$t_o = \frac{l + l_p}{ns} + \frac{l + l_p}{n_{os}} \text{ min.} \quad (76)$$

where l is the length of the cut thread in mm;

l_p is the length of the working part of the tap in mm;

n is the number of revolutions at the working stroke per minute;
 n_o is the number of revolutions at the reverse stroke per minute;
 s is the pitch of the cut thread.

The basic time for cutting threads by machine tapping in dead-end holes, and also with cutting dies, is determined with the same formula (76) at $l_r = 0$.

The basic time for cutting threads with taps is determined according to the formula

$$t_o = \frac{l + l_p}{ns} \text{ min} \quad (77)$$

The basic time for cutting threads with self-opening heads is determined according to the formula

$$t_o = \frac{l}{ns} \text{ min} \quad (78)$$

The basic time for cutting cylindrical cogwheels on milling and toothmilling graduating machines operating with disk modulus milling-cutters is expressed by the formula

$$t_o = \frac{(b + l_{vr})z}{s_m} + \frac{(b + l_{vr})z}{v_{o.x}} + z(z-1) \text{ min} \quad (79)$$

where b is the length of tooth in mm;

l_{vr} is the length of cut-in in mm;

z is the number of teeth of the cut wheel;

s_m is the minute feed at the working stroke in mm;

$v_{o.x}$ is the velocity of the reverse displacement of the table in mm/min;

γ is the time for making the graduation per tooth in min.

The magnitude of the cut-in l_{vr} is determined according to the following formula

$$l_{vr} = \cos \varphi \sqrt{l(D-l)} \text{ mm} \quad (80)$$

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where D is the diameter of the milling-cutter in mm;

t is the cutting depth in mm;

φ is the angle of inclination of the teeth of the cogwheel in degrees.

The basic time for cutting cylindrical cogwheels with straight and spiral teeth on tooth-milling machines is determined according to the formula

$$t_0 = \frac{(D + t_{vr})z}{sn} \quad (81)$$

where s is the radial feed in mm per revolution of element;

n is the number of revolutions of the milling-cutter per minute;

i is the number of turns of the milling-cutter.

The magnitude of the cut-in l_{vr} is determined according to the formula

$$l_{vr} = \cos \varphi \sqrt{t(D-t)} + 1.5 \lg \varphi (M \sqrt{z} + t) \quad (82)$$

where φ is the angle of setting of the milling-cutter in degrees;

t is the cutting-in depth in mm;

D is the diameter of the milling-cutter in mm;

M is the modulus of the cogwheel;

z is the number of teeth of the wheel.

The basic time for cutting wormwheels on gear-milling machines is determined according to the formula

$$t_0 = \frac{2.7Mz}{sn} \text{ min} \quad (83)$$

The basic time for cutting cogwheels on gear-shaping machines with gear shaper cutters is determined according to the formula

$$t_0 = \frac{t_2}{sn} i + \frac{b}{s_1 n} \text{ min} \quad (84)$$

where t is the pitch of the cut wheel in mm;

z is the number of teeth of the cut wheel;
 s is the circular feed of the cogwheel per double stroke of the slide in mm;
 i is the number of generations necessary for cutting the cogwheel;
 h is the magnitude of the radial displacement in mm;
 s_1 is the radial feed per double stroke of the slide in mm;
 n is the number of double strokes of the slide per minute.

The basic time for cutting cogwheels on gear-shaper machines with gear-cutting combs is determined according to the formula

$$t_o = t_{r.kh} + t_{rev} = (z + z_1) \cdot \frac{n_1}{n} + \tau(z - 1) \text{ min} \quad (85)$$

where $t_{r.kh}$ is the time of the working stroke in min;

t_{rev} is the time of the reversal in min;

z is the number of teeth of the wheel;

z_1 is the number of teeth of the overrun;

n_1 is the number of cutters per tooth;

n is the number of double strokes per minute;

τ is the time of the reversal per tooth of the cogwheel per min.

The number of teeth on the overrun is taken in dependence on the number of teeth

of the cut wheel:

when z equals 7 - 48 z_1 equals 2.5-4.5

when z equals 48 - 220 z_1 equals 5.0-8.0

when z equals more than 220 z_1 equals 9.0

The basic time for the shaving process is determined according to the following

formula:

$$t_o = \frac{Lz}{n s_{pr} z_{shv} s \cdot i g} \text{ min} \quad (86)$$

where L is the length of treatment in mm equal to the length of the tooth plus the

cutting-in and overrun equal to 10 mm;

z is the number of teeth of the wheel;

a is the tolerance for shaving in mm;

n is the number of revolutions of the shaver per minute;

s_{pr} is the longitudinal feed in mm per revolution of the cogwheel;

z_{shv} is the number of teeth of the shaver;

s_{ver} is the vertical feed per stroke of the table in mm;

α is the angle of meshing in degrees.

The basic time for cutting bevel gears with straight and inclined teeth is determined according to the formula

$$t_n = \frac{t_m z}{60} \text{ min} \quad (87)$$

where t_m is the time necessary for the treatment of one tooth per second, recommended by the machine builder for the given type of machine and method of treatment;

z is the number of teeth of the cut wheel.

The basic time for rounding the faces of cogwheels with pin milling-cutters is determined according to the formula

$$t_u = \frac{\pi D}{s n} \cdot i \text{ min} \quad (88)$$

where D is the diameter of the graduated circumference of the treated cogwheel in mm;

s is the feed per revolution of the milling-cutter in mm;

n is the number of revolutions of the milling-cutter per minute;

i is the number of passes.

The basic time for circular external grinding in the center with longitudinal feed of the grinding wheel is determined according to the formula

$$t_o = \frac{la}{n s s_{max}} \cdot k \text{ min} \quad (89)$$

where l is the length of the longitudinal stroke of the table in mm;

a is the lateral tolerance;

n is the number of revolutions of the element per minute;

s is the longitudinal feed per revolution of the element in mm;

s_{pop} is the transverse feed of the grinding wheel per pass in mm (cutting depth);

k is a coefficient taking into account the precision of the grinding.

The length of the longitudinal stroke of the table l is determined according to

the formulas:

a) For grinding by passes

$$l = l_1 - (1 - 2m) V_k \quad (90)$$

b) For grinding point blank

$$l = l_1 - (1 - m) V_k \quad (91)$$

where l_1 is the length of the ground surface in mm;

m is the overrun at the boundaries of the ground surface in mm;

V_k is the width of the grinding wheel in mm.

The magnitude of m is taken at 0.25-0.50 of the width of the grinding wheel.

The magnitude of the coefficient k for all forms of grinding work is taken at:

Grinding Precision

in mm

k

0.10-0.25

1.10

0.07-0.10

1.25

0.04-0.07

1.40

0.02-0.04

1.70

when operating with calipers

and verifying plates

2.00

The magnitude of the longitudinal feed s (per revolution of the element in mm) is taken in fractions of the width of the grinding wheel in the following amounts:

For cast iron

At rough grinding up to 0.8 of the width of the grinding wheel,

At finish grinding up to 0.3-0.4 of the width of the grinding wheel;

For steel, untreated and heat-treated, and also for bronze

At rough grinding up to 0.7 of the width of the grinding wheel,

At finish grinding up to 0.25-0.3 of the width of the grinding wheel.

The basic time for round external grinding at transverse feed of the grinding wheel is determined according to the formula

$$t_o = \frac{a}{ns_{ob}} k \text{ min.} \quad (92)$$

where s_{ob} is the transverse feed per revolution of the element in mm (cutting depth).

The basic time for internal grinding with longitudinal feed of the grinding wheel is determined according to the formulas

$$t_o = \frac{a}{n_{dv} s_{dv} v_{pr}} k \text{ min.} \quad (93)$$

$$n_{dv} = \frac{v_{pr} \cdot kh \cdot 1000}{2l} \quad (94)$$

where $n_{dv} \cdot kh$ is the number of double strokes of the table per minute;

$s_{dv} \cdot kh$ is the transverse feed per double stroke of the table in mm (cutting depth);

$v_{pr} \cdot kh$ is the speed of the longitudinal stroke of the table in m/min;

l is the length of stroke of the table in mm.

The determination of the magnitudes of l and k has been explained above.

The basic time for centerless grinding with through feed is determined according to the formulae

$$t_o = \frac{lg + B}{s \cdot q} \cdot f \text{ min.} \quad (95)$$

(96)

$$s_m = \pi \cdot D_v \cdot n_v \cdot \sin \alpha \cdot i \quad \text{mm/min.}$$

where l is the length of the ground surface in mm;

q is the number of elements in the lot ground at continuous flow;

B is the width of the grinding wheel in mm;

i is the number of passes;

s_m is the longitudinal feed in mm/min;

$D_v \cdot k$ is the diameter of the leading grinding wheel in mm;

$n_v \cdot k$ is the number of revolutions of the leading grinding wheel per minute;

α is the angle of rotation of the leading grinding wheel in degrees;

μ is the coefficient of sliding.

The basic time for centerless grinding by the method of cutting-in is determined according to the formula

(97)

$$t_o = \frac{a}{ns_o} \cdot k \quad \text{min.}$$

where a is the lateral tolerance in mm;

n is the number of revolutions of the element per minute;

s is the transverse feed per revolution of the element (cutting depth);

k is a coefficient taking into account the precision of grinding (its magnitude has been reported above).

The number of revolutions of the element is determined according to the formula

(98)

$$n = \frac{n_v \cdot D_v \cdot s}{d} \cdot \mu.$$

where d is the diameter of the element in mm.

The basic time for flat grinding with the face of the grinding wheel on machines of the rotary type is determined according to the formula

(99)

$$t_o = \frac{a}{s \cdot n} \cdot \frac{1}{d} \cdot k,$$

where s_v is the vertical feed of the grinding wheel per revolution of the table in mm;

n is the number of revolutions of the table per minute;

q is the number of elements simultaneously placed on the table.

The basic time for grinding with the face of the grinding wheel on machines of the longitudinal type (the width of the ground surface is smaller than the diameter of the grinding wheel) is determined according to the formula

$$t_o = \frac{La}{v_{pr.kh} 1000 \cdot s_v} \cdot \frac{1}{q} \cdot k \text{ min.} \quad (100)$$

where L is the length of stroke of the table in mm;

$v_{pr.kh}$ is the velocity of the longitudinal stroke of the table in mm;

s_v is the vertical feed of the grinding wheel per pass in mm.

The basic time for grinding with the periphery of the grinding wheel on machines of the longitudinal type is determined according to the equations

$$t_o = \frac{(b + b_1) a}{s_{shir} s_{dv.kh}} \cdot \frac{1}{q} \cdot k \text{ min.}; \quad (101)$$

$$n_{dv.kh} = \frac{v_{pr.kh} 1000}{2L},$$

where b is the width of the ground surface in mm;

b_1 is the lateral overhang of the grinding wheel;

s_{shir} is the transverse feed over the width of the element in mm;

$n_{dv.kh}$ is the number of double strokes of the table per minute.

The transverse feed of the grinding wheel over the width of the element s_{shir}

is taken in a fraction of the width of the wheel

The basic time for grinding the slots of multisplined shafts is determined according to the formula

$$t_o = \frac{La}{v_{pr.kh} 1000 s_v} \cdot z \cdot k \text{ min.}, \quad (102)$$

where z_v is the number of slots (splines) of the shaft.

The basic time for grinding a thread with a one thread grinding wheel is determined according to the formula

$$t_o = \frac{Lz}{ns_{pop}} \cdot k \text{ min.} \quad (103)$$

where s_t is the pitch of the thread in mm;

s_{pop} is the transverse feed per pass in mm (cutting depth).

The basic time for grinding a thread with a multithread grinding wheel is determined according to the formula

$$t_o = \frac{n_m \pi d}{v \cdot 1000} \text{ min.} \quad (104)$$

where n_m is the number of revolutions of the element during the cutting of the thread;

d is the diameter of the element in mm;

v is the rotary speed of the element in m/min.

The basic time for tooth-grinding on machines operating with the generation method with two plate grinding wheels is determined according to the formula

$$t_o = \left(\frac{Ll}{n_o s_{pr}} + i \right) z_{sh} \text{ min.} \quad (105)$$

where L is the length of overhang of the table in mm;

n_o is the number of generations per minute;

s_{pr} is the longitudinal feed per generation in mm;

i is the number of passes;

Y is the time for switching and graduation in min;

z_{sh} is the number of teeth of the ground wheel.

Depending on the working conditions $Y = 0.015 \div 0.03 \text{ min.}$

The stroke length of the table L is determined according to the formula

$$L = B + 2\sqrt{H(D_k - H) + 5}, \quad (106)$$

where B is the width of the ground tooth in mm;
 H is the total height of the tooth in mm;

D_k is the diameter of the grinding wheel in mm.

The basic time for tooth-grinding on machines operating in accordance with the copying method is determined according to the formulas

$$t_o = \frac{2Lz_{zh}}{1000v_{pr.kh}} \cdot \alpha \text{ min.}, \quad (107)$$

$$L = B + \sqrt{H(D_k - H) + 10} \text{ mm} \quad (108)$$

where $v_{pr.kh}$ is the speed of the table in m/min;

α is a coefficient taking into account the graduating time, equals 1.3-1.5.

The basic time for broaching is determined according to the following formula:

$$t_o = \frac{L}{1000v_v} + \frac{L}{1000v_{o.kh}} = \frac{L}{1000} \left(\frac{1}{v_v} + \frac{1}{v_{o.kh}} \right) \text{ min.}, \quad (109)$$

where L is the length of the working part of the broach in mm;

v is the cutting speed (of the working stroke) in m/min;

$v_{o.kh}$ is the speed of the reverse stroke in m/min.

The speed of the reverse stroke is taken at 2-3 times the speed of the working strokes.

The basic time for the honing process is determined according to the following

formulas:

$$t_o = \frac{n_1}{n_2} \text{ min.}; \quad (110)$$

$$n_2 = \frac{v_1 \cdot 1000}{2s}; \quad (111)$$

$$s = L + 2k - l, \quad (112)$$

where n_2 is the necessary double stroke of the honing head for removing the oversize

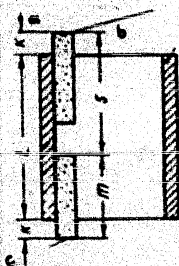


Fig.41 Determination of Stroke of Head for Honing Process

a) abrasive block in upper position; b) element; c) abrasive block in lower position

(for holes in iron elements $n_1 = 60 \div 100$, and for holes in steel elements $n_1 = 400 \div 500$);

v_1 is the velocity of the reciprocating motion in m/min (12-15 m/min);

s is the stroke of the honing head in mm (Fig.41);

L is the length of the treated opening in mm;

k is the overrun of the head in mm (taken at 12-25 mm);

l is the length of the abrasive block in mm (75-100 mm).

The basic time for cutting materials with disk saws (at constant feed is determined according to the formula

$$t_o = \frac{h + l_{vr} + l_p}{s_{r.kh}} + \frac{h + l_{vr} + l_p}{s_{o.kh}} \quad (113)$$

or

$$t_o = \frac{L}{s_{r.kh}} + \frac{L}{s_{o.kh}} = L \left(\frac{1}{s_{r.kh}} + \frac{1}{s_{o.kh}} \right). \quad (114)$$

where h is the thickness of the cut material in mm;

l_{vr} is the magnitude of the cutting-in of the saw in mm;

l_p is the magnitude of the overrun of the saw in mm;

$s_{r.kh}$ is the feed of the working stroke in mm/min;

$s_{o.kh}$ is the velocity of the reverse stroke in mm/min.

The magnitude of the cutting-in depends on the form and dimensions of the cut material, and is taken from existing tables; the cutting-in is taken into account for round materials.

The magnitude of the overrun of the saw is taken at 3-10 mm depending on the diameter of the saw.

The velocity of the reverse stroke may be taken at an average of 2000 mm/min.

The basic working time of saws at variable feed of the working stroke may be taken, with a precision sufficient for the practice, the same as the working time of saws at constant feed of the working stroke.

Determination of auxiliary times

The duration of auxiliary manipulations carried on at the processing of elements and entering into the composition of the auxiliary time, as also the readying-closing time, are determined according to norms formulated on the basis of experimental data obtained as the result of experiments on the work of innovator-pacemakers, and also on the basis of the guiding data of scientific research and planning organizations.

Since a considerable number of diverse manipulations enter into the composition of the auxiliary time, the time norms consist of groups for individual manipulations depending on their character. Accordingly there are established individually:

- a) The norm of the auxiliary time for the placement and removal of the element;
- b) The norm of the auxiliary time connected with the transfer and treatment of one surface and operation;
- c) The norm of the auxiliary time for the verifying measurement of the treated surface.

The norm of the time expended on placing and removing the element relates to a complexity of manipulations (placement, removal, fastening, unfastening) depending on the form and construction of the accessory, the method of setting, fastening and verification of the element, its weight and length, and the method of lifting it.

The norms of auxiliary time connected with the transitions are established for particular grounds of machines (lathes, vertical machines, boring machines, turret machines, drilling machines, milling machines and planing machines), for which are given:

Time for adjustment of the machine in connection with the pass (connecting and disconnecting the feed, putting in and taking out the tool, setting for the cut, etc.);

Time for displacement of the mechanisms of the machine by hand;

Time for taking out the tool (drill) to remove the cuttings.

The norms of the auxiliary times connected with the treatment of one surface are given for round grinding, inner grinding and flat grinding machines; the norm includes the times for putting in and taking out the table or grinding wheel, connecting and disconnecting the feed, changing the working conditions, measuring the elements in the process of treatment.

The norms of the auxiliary times for the operations take into account the expenditure of time for the whole complexity of manipulations involved in the given operation including the time for placing and removing the elements.

The auxiliary time for setting for the cut is given for various forms and methods of treatment, into which all of the manipulations necessary for taking trial cuts enter: starting and stopping of machine, connection and disconnection of the feed, displacement of supports, measurement. The time expended on removing the cuttings, that is, after cutting the metal, does not enter into the auxiliary time. It is, as stated above, included in the basic technological time, into whose determination the calculated length of treating time includes the length of time for taking test cuttings formula (20).

The auxiliary time norms for measurement verification carried out at the execution of the machine operations are established for various shops with measuring implements depending on the method and precision of the measurements and the dimensions

of the elements.

If the time for the verification measurements can be included in the machine time, it may not be included in the norm of the auxiliary time.

The auxiliary time for the measurement of the treated surface carried out with a universal and special measuring implement is included in the time for all of the manipulations connected with the measurement, such as:

- a) Taking the measuring implement and bringing it to the element;
- b) Preliminarily setting the implement for size (if necessary) and measuring the element;
- c) Reading off the result of the measurement;
- d) Returning the implement to its place.

The auxiliary time is calculated as the sum of all of the transitions of the technological process.

Determination of time for technical and organizational services, relaxation and physical relief

The determination of the precise magnitude of this time is extremely difficult because of the diverse conditions and the character of execution of the work.

The determination of the duration of time expended on the execution of the actions entering into it is based on experimental data. In accordance with these data tables and graphs are constructed, calculating the percentual ratios to the basic and operative times, and according to them, the additions to the standard time are made.

The time for technical service at the working place is calculated in a percentual ratio of the basic time. The percentage of the basic time for most machines varies between one and five in dependence of the type and size of the machine. For grinding machines the time for technical service is 3.5-10% (for centerless grinding machines this magnitude reaches 12-18%). As stated above, for permissible simplification, the time of the technical service may be expressed in a percentage of the

operative but not of the basic time (formula (40)).

The time for organizational service at the working place and for physical relief is calculated in a percentage of the operative time. The percentage of the operative time varies between 1.9 and 5.5 depending on the type and size of the machine.

The time for technical servicing of the working place (in percentage of the basic time) and for organizational servicing and physical relief (in percentage of the operative time) for various types and sizes of machines is allowed for in the planning according to approved norms.

In calculated time norms, the times for servicing and physical relief are calculated and totaled for all of the operations of the technological process separately.

H. Determination of the Qualifications of the Workers

When the time norm for the execution of a given operation on a selected machine is established, the qualification class of the workers on the basis of the wage-qualification of the corresponding branch of industry is also determined. The proper relation of the standardized machine operation to the qualification class and the proper determination of the time norm are very important for an effective utilization of the wage fund. The requirements applying to workers for the execution of work with respect to knowledge, experience and degree of independence, predetermine the qualification class of the workers.

The greater the knowledge, experience and independence required for the execution of the given work, the higher is the class of work, and the higher must be the class of worker.

In individual production, the ability to adjust the machines, set elements and tools, use general purpose measuring implements is necessary, so that the qualifications of the workers must be higher. In series production the work is specialized, so that the qualifications of the workers may be lower. In mass production, due to the high mechanization of the work, the differentiation of the process into elementary operations, the employment of automatic machines and automated process, both

highly qualified and less qualified workers can be used.

The present wage schedule has eight qualification classes, whose wages are expressed by a wage coefficient referring each of the schedule classes to the first class.

The wage is established for the first class, and for the other classes the wage is determined by multiplying the wage of the first class by the wage coefficient of the given class.

I. Ways and Means for Higher Economic Efficiency of Technological Processes

After the formulation of the technological process, before proceeding with further calculation of the shop, it is necessary to carry out an evaluation of the formulated process of treatment of the elements.

For this purpose the most characteristic technico-economic indices may serve, some of which are as follows:

1. The production cost of the element, composed of the cost of the material, the basic wages of the productive workers P and the overhead, determined according to the formula

$$S = M + P + R \quad (115)$$

2. The cost of production (shop) of the treated element, composed of the basic wages of the productive workers P and the overhead R:

$$S_o = P + R \quad (116)$$

3. The norms for piecework and calculated piecework times of the complete treatment of the element

$$T_{sh} = \sum t_{sh}; \quad (117)$$

$$T_k = \sum t_k. \quad (118)$$

where T_{sht} is the piecework time for executing all operations on the given element;

t_{sht} is the piecework time of one operation;

T_k is the calculated piecework time for executing all of the operations on the given element;

t_k is the calculated piecework time of one operation.

4. The basic technological time for all operations on the given element

$$T_o = \sum t_o. \quad (119)$$

where t_o is the basic technological time of one operation.

5. The coefficient η_o of machine utilization according to the basic technological time characterizes the degree of mechanization of the treatment process (for further details on the calculation of the coefficient for machine utilization according to the basic time and the coefficient for the loading of equipment in various forms of production, compare further in this chapter). It equals the ratio of the basic to the piecework time, that is

$$\eta_o = \frac{T_o}{T_{sht}}. \quad (120)$$

It must be sought to have this coefficient as high as possible, that is, close to unity. The higher this coefficient is, the greater is the share of the basic (machine) time in the structure of the norm. This means that the total time expenditure for the treatment is made up of a relatively greater percentage of machine time than auxiliary (manual) time, indicating the most effective utilization of the machine. For this, of course, the machine work must occur under the most ideal cutting conditions and with the least expenditure of machine time, auxiliary time and all of the other times connected with the actions of the equipment and the workers for the execution of the work.

The magnitude of this coefficient is greater in flow-mass production than in series production for the reason that in flow-mass production the auxiliary time is

smaller because the process of treatment is more extensively automated and manual manipulations are minimal or wholly absent.

In series production the average magnitude of this coefficient for the shop must be at least 0.60 and in flow-mass production at least 0.70.

6. The coefficient η_3 of loading equipment in relation to time, and characterizing the utilization of equipment in relation to time, is

$$\eta_3 = \frac{C}{S}; \quad (121)$$

where C is the calculated number of machines;

S is the taken (factual) number of machines.

The magnitude of this coefficient may come closer to unity in series rather than in flow-mass production, because in this case the machine can be loaded with different elements. In flow-mass production the machines are specialized, designated for the fabrication of particular elements and the execution of particular operations, so that even with a small coefficient of machine loading (at a small expenditure of operational time) it is impossible to load them with different elements.

It must be sought to have the magnitude of this coefficient close to unity in all cases. In series production its average magnitude for the shop must be at least 0.85 and in flow-mass production at least 0.75.

The closer the magnitude of this coefficient comes to unity the greater is the loading and utilization of the equipment.

The evaluation of the technico-economic effectiveness of the technological process on the basis of the obtained indices is made by analysis and comparison of the latter with the indices obtained in approved and realized projects for analogous productions, or with the indices of existing advanced enterprises containing advanced technology and organization of the production process.

If the found technico-economic index is too low, it is necessary to carry out an analysis for ascertaining the factors leading to the unsatisfactory result, then to

find ways to increase the productivity of the equipment and the work, and to introduce the necessary modifications into the formulated technological process.

Some of the fundamental methods for increasing the technico-economic effectiveness of the technological process are the following:

1. Rational organization, with provisions for the necessary preliminary readying of the work and the working place, timely and precise servicing in the working process, and the most modern planning and maintenance. This may give a decrease in the readying-closing and the auxiliary times and the time for servicing the working area in the working process.
 2. The employment of cutting conditions assuring the most productive work at the least cost of treatment, for which a maximal utilization of the machines with regard to capacity and time and the most economical utilization of the tools must be reached resulting in the lowering of time expenditure for the treatment.
 3. Maximal shortening of the auxiliary time by the employment of special instruments, accessories, rotary tables, magazines, etc., automation and mechanization of the machines and of the verification of the elements, and other modern production paraphernalia.
 4. Employment of hard alloy cutting tools, enabling treatment under accelerated cutting conditions, and resulting in the decrease of machine time.
 5. Employment of several tools for simultaneous treatment of several surfaces and for simultaneous treatment of several elements.
 6. Simultaneous working on several machines and combined skills.
- All of these technical and organizational measures give the possibility of shortening the expenditure of time on the treatment and improving the utilization of the equipment.

18. Formulating the Details of the Technological Process

When formulating the technological process of the production of any product, it is necessary to prepare for each of the elements comprising this product, a detailed

technological chart on the mechanical treatment and a detailed chart on the mechanics' work and assembly of the product.

For the preparation of the technical chart of the mechanical treatment it is necessary to have the following starting materials:

- 1) Working drawing of the element with the technical conditions applying to the given element;
- 2) Assembly drawing of the aggregate into which the given detail enters;
- 3) Production task, establishing the number of products (machines) to be produced and the given elements including the supplied elements;
- 4) Preliminary formulation of the technological route of treatment of the element;
- 5) Operation sketches, preliminarily made by hand, in several variants, illustrating the contemplated methods of treatment;
- 6) Certificates of the metal-cutting machines;
- 7) Catalogs or albums of the machines;
- 8) Catalogs or albums of the cutting tools;
- 9) Albums of the standard accessories;
- 10) Catalogs or albums of the auxiliary implements;
- 11) Guiding material on cutting conditions;
- 12) Norms of the readying-closing and of the auxiliary times;
- 13) Wage-qualification lists.

In the mechanical treatment chart, all of the information pertaining to the elements must be included and the factors entering into the composition of the technological process explained.

The chart must contain (or have annexed thereto) a drawing (sketch) of the element showing the surfaces to be treated, their final dimensions with permissible deviations, the necessary class of cleanness, and also the dimensions of the blank and the tolerances.

NAME OF WORKS		SHOP - MECHANICAL	
I. NAME OF PRODUCT		CHART FOR TREATMENT OF ELEMENT NO.	
II. NAME OF ELEMENT			
III. ELEMENT NO.	IV. DRAWING NO.	V. NAME, MARK, AND MECHANICAL CHARACTERISTICS OF MATERIAL	
VI. KIND AND DIMENSIONS OF NAME	VII. WEIGHT, SAUGH, LISHED, KG, SE	VIII. YEARLY OUTPUT OF PRODUCTS	
IX. NUMBER OF ELEMENTS TO BE TREATED	X. YEARLY OUTPUT OF ELEMENTS	XI. NUMBER OF ELEMENTS IN LOT	
XII. PREPARED BY (SURNAME)		SIGNATURE	DATE
XIII. PREPARED BY (SURNAME)		SIGNATURE	DATE
(SPACE FOR SKETCH, DRAFT)			
DESCRIPTION OF OPERATION		TIME OF TREATMENT IN MIN	
OPERATION	POSITION	TOTAL TIME	
SETTING	TRANSPORTATION	PIECE 1	
TRANSPORTATION	POSITION	PIECE 2	
SETTING	TRANSPORTATION	PIECE 3	
TRANSPORTATION	POSITION	PIECE 4	
SETTING	TRANSPORTATION	PIECE 5	
TRANSPORTATION	POSITION	PIECE 6	
SETTING	TRANSPORTATION	PIECE 7	
TRANSPORTATION	POSITION	PIECE 8	
SETTING	TRANSPORTATION	PIECE 9	
TRANSPORTATION	POSITION	PIECE 10	
SETTING	TRANSPORTATION	PIECE 11	
TRANSPORTATION	POSITION	PIECE 12	
SETTING	TRANSPORTATION	PIECE 13	
TRANSPORTATION	POSITION	PIECE 14	
SETTING	TRANSPORTATION	PIECE 15	
TRANSPORTATION	POSITION	PIECE 16	
SETTING	TRANSPORTATION	PIECE 17	
TRANSPORTATION	POSITION	PIECE 18	
SETTING	TRANSPORTATION	PIECE 19	
TRANSPORTATION	POSITION	PIECE 20	
SETTING	TRANSPORTATION	PIECE 21	
TRANSPORTATION	POSITION	PIECE 22	
SETTING	TRANSPORTATION	PIECE 23	
TRANSPORTATION	POSITION	PIECE 24	
SETTING	TRANSPORTATION	PIECE 25	
TRANSPORTATION	POSITION	PIECE 26	
SETTING	TRANSPORTATION	PIECE 27	
TRANSPORTATION	POSITION	PIECE 28	
SETTING	TRANSPORTATION	PIECE 29	
TRANSPORTATION	POSITION	PIECE 30	
SETTING	TRANSPORTATION	PIECE 31	
TRANSPORTATION	POSITION	PIECE 32	
SETTING	TRANSPORTATION	PIECE 33	
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SETTING	TRANSPORTATION	PIECE 45	
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SETTING	TRANSPORTATION	PIECE 47	
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SETTING	TRANSPORTATION	PIECE 95	
TRANSPORTATION	POSITION	PIECE 96	
SETTING	TRANSPORTATION	PIECE 97	
TRANSPORTATION	POSITION	PIECE 98	
SETTING	TRANSPORTATION	PIECE 99	
TRANSPORTATION	POSITION	PIECE 100	

FORM 2

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Form 3

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The chart has a particular form, with columns, in which there are entered all of the data pertaining to the element and the technological process of its production.

The chart of the mechanical treatment (Form 2) usually consists of two principal parts: the first (upper) part of the obverse side of the chart, in which all of the necessary information of the treatment of the element and its blank, and also the drawing (sketch) of the element are placed, and the second (lower) part of the obverse side, in which the contemplated plan of treatment and all of the calculations pertaining to it are entered (the continuation of this part is placed on the reverse side of the chart).

Sketches of the transitions are annexed to the chart illustrating the position and fastening of the elements, the position, fastening and type of tools, the accessories used, and the surfaces to be treated.

The dimensions, with permissible deviations obtained as a result of the treatment in the given operation, and also the necessary class of cleanness of the treatment must be indicated on the sketches.

Form 4

						(a)	(b)					(c)				(d)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	

1. Serial No.; 2. Element No.; 3. Drawing No.; 4. Name of element; 5. Number of elements to product; 6. Name of operation; a - Machine; 7. Name and builder, mark; 8. Principal dimensions of machine; b - Time of treatment on one element; 9 - Basic in minutes; 10. Piece for piece-calculated in minutes; 11. Total on set of elements for one product in hours; 12. Accessories; c - Tools; 13. Cutting; 14. Measuring; 15. Auxiliary; d - Qualifications of workers; 16. Profession; 17. Class

Form 5

0	(b)		(d)		(e)		(f)		(h)	
2	(a)	(c)			(g)					(i)
4	(k)		XII.		I.					
6	A.		XIII.		II.					
8	B.		XIV.		III.					
10	C.		XV.		IV.					
12	D.		XVI.		V.					
14	E.		XVII.		VI.					
16	F.		XVIII.		VII.					
18			XIX.		VIII.					
20			XX.		IX.					
22			XXI.		X.					
24					XI.					
26										
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56										

Form 5

a - Works; b - Shop; c - Section or group; d - Instruction-norms chart on operations of mechanical treatment; e - Prepared by; f - Date; g - Verified by; h - Operation No. ...; i - To technological chart No. ...; j - Place for sketch; k - Time norm on one element on operation; l - Min; A - Readyng-closing time; a) On lot; b) On element; B - Basic time; C - Auxiliary time; D - Time on servicing working place; E - Piece time; F - Piece-calculated time; I. Product; II. Name of element; III. Element No.; IV. Drawing No.; V. Material: name, mark and mechanical characteristics; VI. Form and dimensions of blank; VII. Weight: rough...kg; finished ... kg; VIII. Yearly output of products; IX. Number of elements to one product; X. Yearly output of elements ... pieces; XI. Number of elements in lot ... pieces; XII. Name of operation; XIII. Class of work; XIV. Machine; XV. Model and builder; XVI. Principal dimensions; XVII. Power ... kw; XVIII. Accessories; XIX. Cooling; XX. Number of details treated simultaneously; XXI. Number of machines operated simultaneously by one worker; 1. Designation of setting, position; 2. Transition No.; 3. Maintenance of setting and transition; m - Tools; 4. Auxiliary; n - Cutting; 5. Name; 6. Mark, material; 7. Measuring; 8. Treated surface No.; o - Dimensions of treated surface in mm; 9. Diameter; 10. Length; 11. Width; 12. Cutting-in and overrun; 13. Calculated length; 14. Lateral tolerance in mm; p - Conditions of treatment; 15. Cutting depth t in mm; 16. Number of passes l; 17. Feed per revolution or double stroke s_z in mm; 18. Cutting speed v in m/min; 19. Number of revolutions or double strokes n/min; 20. Feed s_m in mm/min; 21. Effective power N_e in kw; 22. Basic time in minutes; q - Auxiliary time in min; 23. For putting in and taking out elements; 24. For changing tools; r - For changing conditions; 25. Feed; 26. Revolutions or double strokes; 27. In connection with transitions; 28. For verification measurements; 29. Total

For combining the resultant information of the treatment of the given element, a compound chart of the technological process (Form 3) is prepared, in which are listed the principal technological data on the operations and on the number of the given elements required for one product (machine).

The chart of treatments according to Form 2 is annexed to this compound chart.

When the technological process is not formulated in detail but limited to the establishment of the sequence and route of the operations, showing the machines, accessories, tools and number of workers necessary for the execution of the contemplated operations, as well as the times for the treatments, established by means of comparison, analogy or approximate calculation, a simplified technological chart (Form 4) is prepared.

For detailed calculations according to the norm, an instructions-norms chart is also prepared as a supplement to the chart of the treatments. A separate chart must be prepared for each of the operations. In it is indicated in detail how the treatment was carried out at each transition, the conditions under which the treatment must be carried out, how the time norms for the operations are established, etc. These charts are accompanied by sketches illustrating the treatments, the scheme of the adjustments of the machine and the scheme indicating the manipulations for operating the machine.

The instructions-norms chart has various forms, differing more or less in the completeness of the data pertaining to the process of treatment. A specimen of an instructions-norms chart is presented here as Form 5.

Methodical Explanation for Preparation of Technological Charts of Mechanical Treatments

All of the fundamental positions for the formulation of the technological process are formulated, to make their use more convenient, in compressed form with methodical explanations placed below them for the preparation of the technological chart. Graphic representations of the tentatively designated positions of the elements,

tools and accessories of the machines for various forms of treatment are presented in Figs.34-37.

1. A separate chart of the mechanical treatment and a separate chart of the mechanics' work and the assembly of the product is prepared for each of the elements when the technological process of the production of the product is formulated.

2. In the chart of the mechanical treatments the data characterizing the given detail: name of product, name of element, detail number, drawing number of element, characteristics of material, kind and dimensions of blank, rough and finished weight, yearly output of products, number of elements to product, yearly output of elements including spare parts, number of elements in lot, date and signature of person preparing and verifying the chart, are entered in the first (upper) part in the respective columns.

On the left hand side of the upper part of the chart a drawing (sketch) of the element is annexed. On the drawing (sketch) the surfaces to be treated, their dimensions with permissible deviations and the required class of cleanness of treatment according to GOST 2789-51, must be indicated.

Moreover, the configuration of the blank with indication of the tolerances must be indicated on the drawing (sketch) in dotted lines or with crayon. On the drawing (sketch) of the element, the technological markings of the surfaces to be treated and adjusted with designation of their serial numbers must be made.

The second (lower) part contains the columns for listing the formulated technological process with subdivisions in operations, settings, transitions, positions, giving the necessary machines, accessories, cutting tools and measuring implements, and also showing the calculated dimensions of the treated surfaces, cutting conditions, time norms on the fundamental components class (qualifications) of work, and by operations, the number of machines necessary for carrying out the yearly task.

3. The plan for the mechanical treatment of the element is divided into operations, settings, transitions, and positions.

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If the element is made of rolled material, the operation of cutting the blank must also be included in the process of treatment.

4. The operations are designated by Roman numbers, the transitions by Arabic numbers and the settings by capital letters. These designations are placed in the corresponding columns of the chart of treatments (1-4).

The serial numbers of the transitions are entered for each of the operations separately beginning with the first.

5. In column 5 of the chart of treatments, "Description of the Operations, Settings, Transitions, Positions", the mechanical treatments of the element are entered, which also include the intermediate mechanics' and other operations necessary for the further mechanical treatment (marking, soldering, filling, etc.). The final mechanics' operations are entered in a separate chart of the mechanics' assembly work.

Here, the abbreviated names of the operations according to the kind of treatment are entered (for example, milling of surface, drilling three holes of 25 mm diameter, etc.). Each transition is described in detail, with indication of the serial number of the treated surface, for which the numbers of all the treated surfaces must be entered on the sketch of the transition. After the indication of the operation the "setting of the element" is described. Next, the transitions and settings are entered in the order of the sequence of the treatments. After the last transition "remove the element" is written.

6. For each of the transitions, a sketch of the transitions of the treatments with schematic tentative designation of the method of fastening the element, position of the tool and place of treatment is represented in the same column or in an album annexed to the chart. The latter is designated by number, or by a heavy line, or by a colored line (red).

7. In the column "Designation of the Treated Surface" the number (or other tentative designation) of the surface to be treated in the given transition is indicated.

8. The machine is characterized by name, principal dimensions, type, power of

the electric motor, and name of builder.

The name of the machine according to the type of treatment, for example, lathe, milling, vertical grinding machine, etc., together with the principal dimensions of the machine: for lathes the height of the centers and the clearance between centers, for milling machines the length and width of the table, for vertical drilling machines the greatest diameter of the drill, etc. are entered in the column "Name, Principal Dimensions".

In the column "Type, Model", the type or mark of the machine, for example: Type 1D62, is entered.

9. In the column "Accessories", all of the accessories necessary for the treatment of the given operation are entered. If the accessory is a regular one of the machine, for example, a support, clamp, etc., its name is indicated. If the accessory is special, "special" is indicated.

10. The name and size of the cutting tool used, and the sort and mark of the material of the cutting part, for example, drill spiral diameter 20 mm of highspeed steel face milling-cutter diameter 180 mm, $z = 12$, VK8 etc., are entered in the column "Cutting Tool".

Operation with cooling or without cooling is noted after the name of the operation.

11. The measuring implements used and a brief characterization, the principal dimensions and precision of the implement are indicated in the column "Measuring Implements"; for example, horseshoe gauge 50 A₃, dial gauge 0.01, trammel 200, etc.

12. In the column "Number of Elements Treated Simultaneously", the number of elements present on the machine simultaneously and treated at the same time is indicated.

13. In the column "Number of Machines Operated Simultaneously by One Worker", the number of workers and, in the denominator, the number of machines for simultaneous operation is indicated.

14. The dimensions of the treated surface of the element, placed in the separate

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column for them, are given in dependence of the working motions of the element and the tool. For machines with rotary motion, the starting diameter, the diameter after treatment, and the length of treatment are given, and for machines with forward motion, the length and width of the treated surface. The diameter of the element to be treated, necessary for a given number of revolutions for the given cutting speed, is indicated according to the greatest dimension of treatment (blank or preceding transition), that is, the diameter of the last treatment, which when executed leaves the tolerance for the next treatment, is indicated. The length of the element treated by planing, necessary for a given number of double strokes in the given cutting speed, is indicated in the direction of the working motion and the dimension of the width, in the direction of the feed.

The dimensions of the entrance and departure of the tool, which are determined by calculation or are taken according to the norms, depending on the form of treatment, are entered in the column "Cutting-In and Overrun".

For the determination of the calculated length of treatment, which is entered in the column "Calculated Length or Width", it is necessary to add to the length of the treated surface, including the length tolerance (if there is one), the magnitude of the cutting-in and overrun (or entrance and departure) of the tool and the total length of transition comprising the test cutting.

15. In the column "Tolerance for Lateral Treatment in mm", the magnitude of the tolerance pertaining to one side of the element before the beginning of the given transition is entered.

For the first transition, the magnitude of the tolerance is determined by comparing on the drawing the dimensions of the blank and the dimensions of the final treatment of the element or in the Table of Norms, the tolerances from the corresponding guide data.

For each successive transition, the magnitude of the tolerance equals the magnitude of the original tolerance minus the sum of the magnitudes of the cutting depths

of all the preceding transitions.

16. The cutting conditions are established separately for each transition on the basis of calculation or the guide norm data. The cutting procedure must be optimal in correspondence with the number of revolutions, feed, power and torque of the machine shown in the certificate of the machine.

In the absence of a certificate of the machine, the cutting procedure is established according to the data of the catalog and the guide data, starting with the cost of the tool, and followed by verification of the corresponding power of the machine.

In the corresponding columns the cutting components are entered: cutting depth t , number of passes i , feed per revolution or double stroke s_0 or feed per minute s_m , cutting speed v , number of revolutions or double strokes n .

The cutting depth t is indicated in millimeters for the given transition depending on the tolerance, power of the machine, and dimensions of the treated element.

The number of passes i necessary for removing the tolerance remaining for the given transition at the selected cutting depth must be as small as possible for the coarse treatment.

The feed is determined according to the guide data, and is indicated according to the type of machine. For work on lathes and turret machines, the feed of the cutter is indicated in millimeters per revolution of the spindle; for planing work on longitudinal planing machines, the feed of the cutter is indicated in millimeters per double stroke of the table; for planing work on transverse planing machines, in millimeters per double stroke of the cutter; and for drilling work, in millimeters per revolution of the drill.

For milling work, the feed of the product is indicated in millimeters per revolution of the milling-cutter or per minute. In the milling of splines with grooving milling-cutters, the vertical and longitudinal feeds are indicated across the inclined line; upwardly, above the line - the vertical feed; downwardly, below the line -

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the longitudinal feed. For gear shaping machines of Types 512, 516, the radial feed is above the inclined line; the circular feed (generating feed) - below the line. For gear-cutting machines operating with hobbing cutters, the feed of the milling-cutter is indicated in millimeters per revolution of the table or of the element.

For external round grinding in centers, the feed is indicated per revolution of the element. For internal and flat grinding, the transverse feed is indicated per revolution or double stroke of the table. (For these machines, the magnitude entered in the column "Grinding Depth" is repeated in the column "Feed".)

The minute feed, entered in the corresponding column, is obtained by multiplying the magnitude of the feed per revolution or double stroke s_0 by the number of revolutions or double strokes n per minute.

The cutting speed is entered, calculated in meters per minute. It is determined in lathe facing and undercutting according to the outside diameter of the element, and in boring, according to the diameter obtained after boring.

In drilling and milling, the cutting speed is determined according to the outside diameter of the cutting tool. In working with gang cutters, the cutting speed is taken corresponding to the diameter of the largest cutter of the given gang.

For work on longitudinal planing machines, the motion of the table at the working stroke is taken as the cutting speed.

For work on transverse-planing and shaping machines with link drive, the average speed of the cutting prism at its working stroke is taken as the cutting speed.

For milling teeth on machines operating with disk or hobbing cutters, the cutting speed as determined by the diameter of the cutter is indicated.

In work on gear-cutting machines with reciprocating motion, the cutting speed as determined by the number of double strokes of the tool is indicated.

Since for grinding work, the cutting speed does not enter directly into the formula of the basic time, and for the determination of the basic time it is necessary to know the rotary speed or reciprocating displacement of the element or grinding

wheel, therefore in the column "Cutting Speed", two speeds are entered across the inclined line: upwardly the rotary speed of the grinding wheel and downwardly the rotary speed or reciprocating motion of the grinding wheel or element.

In the column "Number of Revolutions or Double Strokes", the factual number of revolutions or double strokes per minute as shown by a certificate of the machine is entered, and correspondingly, the cutting speed, and, in the absence of a certificate the theoretical number of revolutions or double strokes per minute corresponding to the indicated cutting speed are indicated.

The number of revolutions taken may be retained for several transitions (particularly for a small length of the treated surface), although on the condition that the cutting speed with the decreasing diameter of the element does not decrease so much that it would be more advantageous to switch the machine to the next higher number of revolutions. For this it must be verified whether it is more advantageous to continue the treatment with the same number of revolutions or to expend the auxiliary time for changing the number of revolutions. The same considerations also apply to the question of changing the feed.

17. In the column "Effective Power in kw", the power on the tool expended for the given transition is entered. Calculation of the power is made on the basis of the given guide data. The power cannot be calculated for all transitions of operations but only for the greatest loading. If several cutters are operated simultaneously (on turret machines, multicutter machines and the like) the power is indicated as the sum for all tools.

18. The readying-closing time is taken for the whole lot. Its magnitude as taken from the Table, is divided by the number of pieces in the lot, and the obtained magnitude expresses the time expended on one element. It is entered for all of the operations in the form of a fraction, whose numerator is the time for the whole lot and its denominator the number of elements in the lot.

19. The basic technological time is calculated according to formula, and is entered

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ed separately for each transition.

The time for the cutting-in and overrun of the tool for all machines, of the reverse stroke for planing, broaching, gear-cutting and other machines, is included in the basic time.

20. The auxiliary time, taking into account all of the auxiliary, manual manipulations on the element, machine and tool, and also the measuring manipulations, is entered for each transition separately. Its magnitude is taken according to the norms.

Remarks on 19 and 20: When several tools are operated simultaneously in one transition, for example, in work on turret, vertical and other machines, the working time of the tools, including the working time of the other tools, is enclosed in parentheses.

After enumerating all transitions entering into the operation, a line is drawn and the total of the basic and auxiliary times for all of the transitions entered. For this the times not enclosed in parentheses are added.

21. The time for the technical and organizational servicing of the working place and the time for relaxation and natural relief are entered in the chart of treatment in the total for all operations of the line.

Its magnitude is taken according to norm in the corresponding percentage.

22. The piece time for all operations on the given element is entered as the total for the line. For this, the sum of the basic times for all transitions of the given operation, the sum of the auxiliary times for all transitions of the operation, the times for the technical and organizational servicing of the working place and the physical needs for all operations, and the sum total of all of the time components, that is, the piece time, are entered in the corresponding column.

23. The piece-calculated time, obtained by adding the piece time and the readying closing time applying to one element (if this occurs), is entered in the next column.

If several elements are treated simultaneously, the time(piece or calculated)

for one element is determined by dividing the sum total of the treating times (piece or calculated) of the blank by the number of simultaneously treated elements obtained from the given blank.

24. The class of worker to execute the given operation as determined by the degree of complexity of the operation and the precision of treatment according to the corresponding classification list, is entered in the column "Class".

25. The columns "Required Number of Machines" and "Required Number of Workers" are filled in for flow production, when these magnitudes are determined for each operation.

After preparing the complete plan of treatment and determining the times for all operations, the compound chart of the technological process of mechanical treatment is prepared. In the upper part of the compound chart, the data characterizing the element are entered, while in the lower part, the operations showing the shop in which the given operation is carried out are enumerated together with a brief characterization and indication of the number of machines required. The time for the treatment of one element and of the set of the given elements for one product (machine), the time expended by one worker on one element and on the set of elements for one product, and the qualifications (class of work) are also entered.

19. Determination of the Required Amount of Equipment

(Metal-Cutting Machines)

The determination of the amount of equipment necessary for the execution of the given production program is the fundamental and most serious problem in the planning of a shop. Incorrect calculation of the amount or incorrect selection of the type of equipment leads to a surplus or deficit, but also to an imbalance thereof. A surplus of equipment leads to its incomplete utilization, also increasing the nonproductive expenditures for its procurement, adjustment and maintenance, and increasing the floor space for its placement. When there is a deficit of equipment, the possibility of fulfilling the production task is absent. With this necessity for supple-

menting it, difficulties due to space limitations, and spacing as connected with the sequence of execution of the technological operations, are unavoidably encountered. Even the possibility of enlarging the floor space of the shop brings about the necessity of replacing the equipment. The proper calculation of the number of machines must at the same time provide for its completeness. If the machine equipment is composed in such a way that individual groups of machines do not possess the corresponding throughput capacity, the shop will be unable to turn out the given number of finished products, because individual stages of the treatment will be either too late or too early. By the incorrect selection of machines according to type and size, suitable machines may not be available for certain operations.

All of these serious consequences of inaccurate planning and selection of the equipment necessitate the application of attention and great precision to the solution of the problem.

The determination of the number of machines of the mechanical shop necessary for treatment of the elements according to the given program is arrived at according to two methods: 1) according to the technological process, and 2) according to the technico-economic indices.

The adoption of one or the other method of calculation depends on a number of conditions: type of production, presence of information on the subject of production (drawings, lists and its various forms, characterizations of products, etc.), and the required precision of calculation, and also on the purpose of the calculation, that is, for preliminary consideration and approximate calculations or for final decision.

The first method is adopted for detailed planning on the basis of precise enumeration of the products to be produced, a given technological process, and the time norms worked out for each element. This method is applied to the planning of mechanical shops for series and mass production.

The second method is applied to enlargement projects when the list of products

is not precisely established, to the formulation of a projected task, to the planning of mechanical shops for individual and small-series production with an extensive and diverse list of products, and to the formulation of projected tool and reconditioning mechanical shops.

The most precise determination of the necessary number of machines and the best selection of the necessary complement of machines is only possible on the basis of the technological process.

The number of machine tools necessary for the treatment of the elements for the given number of machines according to the yearly production program is calculated on the basis of the time norms necessary for the execution of each of the operations on all of the elements for the given number of machines to be turned out in a year.

It must be borne in mind that the spare parts for the products must enter into the number of elements determining the yearly production program.

Data on the list and numbers of spare parts, if unobtainable, can be taken into account in series production by increasing the number of machine and man hours necessary for fulfilling the production program, according to the machine tools on which the spare parts can be treated (approximately, in heavy and general machine building by 5-6%, and in automobile and tractor building by 20-22%).

Below are discussed methods of determining the number of machine tools on the basis of the technological process for series, flow-mass and flow-series (alternating-flow) production.

A. Determination of the number of machine tools and the coefficient of loading and utilisation thereof, according to the basic time in series production

The method here described for determining the necessary number of machine tools for series production is also employed for individual production when the data on the treating times of the elements assigned to each type of machine tool are available.

When calculating the number of machine tools necessary for the treatment of the

elements according to the given production program, it is necessary to determine, on the basis of the formulated technological process and the calculated time norms for execution of each of the operations on all of the elements, the time expended for the treatment of the entire number of elements per year of each kind on each machine tool.

The required number of machine tools of a given type is obtained by dividing the sum of the time norms necessary for the treatment of the number of elements per year by the actual number of working hours per year for one machine tool in the corresponding number of working shifts:

$$C = \frac{T_k}{F_0 m}, \quad (122)$$

where C is the necessary (calculated) number of machine tools for a given time;

T_k is the sum of the time norms in hours necessary for the treatment of the number of elements per year on the machine tool of a given type;

F_0 is the actual yearly number of working hours per year for one machine tool in one shift;

m is the number of working shifts of the machine tool in 24 hours.

The sum of the time norms T_k is calculated (for series and individual production) on the basis of the piece-calculated time and the detailed yearly production program of the mechanical shop including the spare parts for the products.

The reason why, in series as well as in individual production, the piece-calculated time must be taken as the basis for the calculation of the necessary number of machine tools is that for these forms of production the readying and adjustment of the machine tools, tools and accessories and other manipulations, and the times whose execution enter into the composition of the readying-closing time, occur in the working time. Therefore, while the machine tools in these periods are occupied, although indirectly, with working on the removal of cuttings, they are not producing. Specifically, this expenditure of time must enter into the loading of the machine tool.

The piece-calculated time for the treatment of one element (in minutes) accord-

ing to formula (36) is

$$t_n = t_{shf} + \frac{T_{n,s}}{n} \text{ min.}$$

The piece time for the treatment of one element (norm of the piece time) according to formula (33) is

$$t_{shf} = t_o + t_v + t_{i.o} + t_{o.ob} + t_d \text{ min.}$$

The sum of the time norms (in formula (122)) for series production equals the productive piece-calculated time for the treatment of one element of the number of given elements per year, that is

$$T_k = \frac{t_k D}{60}, \quad (123)$$

where T_k is the sum of the time norms (piece-calculated) in hours necessary for the treatment of a number of elements for a year on a given type and size of machine tool;

D is the number of identical elements treated in a year on a given type and size machine tool.

In the treatment of nonidentical elements on a given type and size machine tool, the sum of the time norms for the treatment of these elements equals the sum of the productive times for the treatment of one element out of the number of identical elements per year, that is

$$T_s = \frac{t_{k1} D_1}{60} + \frac{t_{k2} D_2}{60} + \frac{t_{k3} D_3}{60} + \dots + \frac{t_{kn} D_n}{60} \quad (124)$$

or

$$T_s = \frac{\sum t_k D}{60}, \quad (125)$$

where $t_{k1}, t_{k2}, t_{k3}, \dots, t_{kn}$ are the piece-calculated times for the treatment of the

$D_1, D_2, D_3, \dots D_n$ are respectively the numbers of nonidentical elements treated in a year on a machine tool of a given type and size.

As can be seen from formula (122), to calculate the necessary number of machine tools it is necessary to know the actual number of working hours per year of one machine tool.

The actual (calculated) number of working hours per year of one machine tool, called the actual time fund of the machine tool, is the time during which the machine tool must be occupied with work. This time equals the nominal number of hours per year (nominal time fund of the machine tool) less the time the machine tool spends in the reconditioning department), as accounted for by the coefficient:

$$F_d = Fk. \quad (126)$$

where F_d is the actual time fund of the machine tool (yearly) per shift in hours;

F is the nominal time fund of the machine tool (yearly) per shift in hours;

k is a coefficient accounting for the time the machine tool spends in the reconditioning department.

The nominal and actual time funds may be applied to one, two or three shifts depending on the prevailing work schedule. The number of hours per year for one shift must be taken as the basic magnitude, and for work in several shifts this is accounted for by the multiplier m in formula (122).

The nominal time fund of a machine tool (yearly) in hours for one shift is

$$F = \Phi H. \quad (127)$$

and for several shifts

$$Fm = \Phi Hm. \quad (128)$$

The actual time fund of the machine tool (yearly) in hours for one shift is

$$F_d = F \cdot k = \Phi Hk. \quad (129)$$

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and for several shifts

$$F_{\delta m} = F_k m = \Phi H k m, \quad (130)$$

where Φ is the number of working hours in the year;

H is the number of working hours in the shift.

As a rule, in planning mechanical shops, the two-shift working schedule for eight working hours in the shift is used.

To simplify the calculation for three-shift work, it is necessary to take as the magnitudes of F and F_{δ} , in formulas (122), (128), and (130) and all the following formulas, the averages for all three shifts, or to take their productive hours F_m and $F_{\delta m}$ equal to the total number of hours in the three shifts, since the number of working hours in the third shift is less than in the first and second shifts (third shift usually 7 hours).

By substituting in eq.(122) the value T_k from eqs.(123) and (125) as well as the value F_{δ} from eq.(126), we obtain the required (calculated) quantity of machine tools of the type:

for similar working parts

$$C = \frac{T_k}{F_{\delta m}} = \frac{t_k D}{60 F k m}; \quad (131)$$

for dissimilar working parts

$$C = \frac{T_k}{F_{\delta m}} = \frac{\sum t_k D}{60 F k m}. \quad (132)$$

The numerical values of the magnitudes k , F , and F_{δ} are used on the basis of the following considerations:

- a) When workers are excused or absent from their working place for a good reason, they must be replaced by other workers, because the machine must not stand idle;
- b) Idle time for machines may include only the time for reconditioning, since periodical inspections, verifications, current and ordinary repairs must occur on

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nonworking days and in free shifts.

The idle machine time for reconditioning, taking into account the coefficient k , is based on the number of hours necessary for the reconditioning which depends on the complexity and size of the machine, the working conditions, and the duration of service. Usually this time is calculated as a percentage of the nominal time fund per year within 3.5 to 6%, and, specifically, 4% for small and medium machines, and 6% for large and complicated machines may be taken for the two shift working schedule.

To simplify calculations, some planning organizations take an average percentage

Table 6

Number of Hours per Year of Actual and Nominal Machine Time Funds

Number of Shifts	Number of Working Hours in Shift	Number of Working Days in Year	Nominal Time Fund per Year in Hours	Actual Time Fund per Year in Hours (idle for reconditioning)				
				6% $k = 0.94$	5% $k = 0.95$	4.5% $k = 0.955$	4% $k = 0.96$	3% $k = 0.97$
1	8	307	2456	2309	2333	2345	2358	2382
2	8	307	4912	4618	4666	4690	4716	4764
3	8 in the first and second and 7 in the third shift	307	7061	6637	6708	6743	6779	6849

value for all machines at 4.5 or 5%. In the three-shift working schedule, the percentage increases to 5.5 - 6.

In the planning for rebuilding works, when the use of old equipment is contemplated, the repair time for all machine tools may be taken at 5 - 6%.

By substituting in formulas (128) and (130) the numerical values $\phi = 307$ working days, $H = 8$ working days, $m = 1, 2, 3$ shifts and various values of the coefficient k , we get the number of hours per year of the nominal and actual funds F_m and $F_{\phi m}$ for the operation of the machines in one, two and three shifts. For this the third shift works 7 hours.

No.	Name of Part	No. of Part	Material	Wt. in kg		Number of Pieces for each Machine	Lathe				Turret Lathe				Mill	
				rough	net		$h_1 \times l_1$ mm	$h_2 \times h_2$ mm	$h_3 \times h_3$ mm	Multi-blade	1 mm	2 mm	3 mm	Boring Machine mm	Turning lathe mm	Horizontal $B_2 \times L_2$ mm
1																
2																
3																
4																
5																
6																
...																

Total minutes per machine

Total hours per machine

Number of hours of yearly program (X*)

Spare parts (X*)

Calculated number of machines

$$C = \frac{I_2}{T_{2m}} = \frac{\sum I_2 \cdot D}{\sum (D \cdot F \cdot S \cdot m)}$$

Cooperation

Number of machines used S

Coefficient of machine loading

$\frac{C}{S} \cdot 100$ (in percent)

Average coefficient of machine loading by shops $\frac{\sum C}{\sum S}$

*The extra in percent for the treatment of spare parts is provided for when they are not included in the total number of elements according to the yearly production program.

Form 6

By taking various values of the coefficient k to account for idle machine time for reconditioning, in the amounts respectively of 6.5, 4.5, 4 and 3% ($k = 0.94 \frac{1}{2} + 0.97$) of the nominal time fund per year, we get for the various working conditions the number of hours per year of the actual time fund listed in Table 6.

For the number of machines calculated on the basis of the above formulas, a table of the machine loading (Form 6) is prepared.

In planning according to an exact (detailed) program, all of the elements to be produced in the shop, the serial number of each, the number of pieces per machine, are entered in Form 6. On the lines, the machines necessary for the treatment of the elements (name, type, principal dimensions) are entered. The time norm for an operation on a given machine, obtained by multiplying the time for the operation, taken from the technological chart, by the number of given elements, is entered in the column for each type-size machine. Next, the times for each type-size machine are totaled. The total is the number of hours on this machine tool necessary for the production of one machine. The time obtained for each machine is multiplied by the number of machines produced per year, as a result of which the sum total of the times of the yearly loading in hours for each type-size machine tool is obtained. This total time in each column (yearly loading) must be divided on the basis of formulas (131) and (132) by the actual yearly time fund of the machine tool according to the number of shifts employed. The necessary number of machines of each type-size is obtained as a result.

If the program of the shop includes the production of several types of machines it is necessary to prepare for each of them a separate loading table, and based on them, the compound loading table for all machines of the program.

In planning according to an allocated program, the loading time of each type-size machine tool treating the elements of the "calculated" machine, must first be entered in the table, after which the times for the elements of the remaining machines of the given group are entered. The loading time is determined according to the co-

0 efficient of allocation based on the capacity of each machine of the given group re-
2 ferred to as the calculated, or the coefficient as taken according to eq.(43), on the
4 basis of the element-calculated weight-ratio, and compared with it.

6 By multiplying the operational time of the elements of the "calculated" machine
8 for each type-size machine tool by the derived (or taken) coefficient, the time for
10 similar elements of each machine of the given group can be determined. Equation (43)
12 also enables the derivation of the increased coefficient for the machine as a whole;
14 in this case it is necessary to compare the sum of the times of the mechanical treat-
16 ment and the total weight of the finished machine.

18 By combining the total times for the elements of all machines of the entire
20 group according to each type-size of machine tool, the necessary number of machine
22 tools of each type-size can be determined.

24 For a program with a long and diverse list, a technological chart cannot be pre-
26 pared for all of the elements of the produced machine. In this case the loading of
28 the machine tools can be calculated by groups of elements for the various machines.
30 All of the elements of these machines similar to each other in character of treat-
32 ment and size are divided into groups (beds, frames, supports, plates, shafts, axles,
34 pulleys, flywheels, bushes, cogwheels, etc.). For each group of elements, a techno-
36 logical chart for two (large and small) or three (large, medium and small) elements
38 is prepared. These two-three elements are calculated as representative of the groups.
40 The treatment time for elements of intermediate sizes can be determined according to
42 a graph (Fig.39) constructed according to the calculated elements, or according to
44 eq.(43).

46 In the preparation of the loading table, the time for one element for each type-
48 size machine tool is multiplied by the number of elements of the given name accord-
50 ing to the yearly program.

52 The further course of calculations is analogous to that already described.

54 In the planning of shops for the production of products produced by existing
56

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works, the technological process can only be formulated on the basis of the most characteristic and fundamental elements. The times calculated for the treatment of these elements are compared with the times for the treatment of analogous elements in the actual works where the coefficients of deviation, which are applied as correction coefficients to the time norms of all the remaining elements of the actual works, are determined. The treating times of all elements obtained in this way are entered in the loading table, after which the calculation of the number of machine tools is determined in the usual order.

The number of tool machines calculated according to the above formulas may be a fraction which is then rounded to a whole number, called the taken number of machine tools S .

If, in the calculation of the number of machine tools, the fraction obtained is small (less than 0.5), but the loading of the next size of the same type of machine tool is insufficient, then this fraction, expressing a part of a machine tool, is added to the calculated number of machine tools of the next larger size. Machine tools loaded in this way are called "cooperative" machines. Under this heading, with a minus or plus, the fractional magnitudes as taken from the column of the given machine tool (minus) and put in the column of the next larger machine tool (plus) are entered in the loading table (after the line "Calculated number of machine tools") in the columns of the corresponding tool machines.

If, however, the calculated number of machine tools is obtained with a small fraction, and a machine tool of the same type in the next larger size is not available, then the possibility of increasing the load of the machine tool, by shortening the time norm (accelerating the cutting speed and shortening the auxiliary times), or by transferring the treatment of some of the elements to an incompletely loaded machine tool of another type, for example, from a planing to a milling machine or conversely, must be investigated. It is particularly important to try to increase the load of large and expensive machine tools for the purpose of utilizing them more

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fully.

The total number of required machine tools for the projected shop S_u is determined as the sum of the taken numbers of machine tools of each type-size, that is

$$S_u = \sum S. \quad (133)$$

The coefficient of loading (for further details on this coefficient, see under the heading "Evaluation of Technico-Economic Effectiveness of the Technological Process" in this chapter) determining the number of machine tools (or group of machine tools) necessary for performing the given work, is expressed by the following formula:

$$\eta_1 = \frac{T_k}{F_0 m S}. \quad (134)$$

where η_1 is the coefficient of loading (by time);

T_k is the total calculated time in hours (for individual and series production;

F_0 is the actual yearly time fund of the machine tool in hours;

m is the number of working shifts;

S is the taken number of machine tools.

When this formula is compared with formula (122) we get

$$\eta_1 = \frac{T_k}{F_0 m S} = \frac{C}{S}, \quad (135)$$

that is, the coefficient of loading equals the ratio of the calculated number to the taken number of machine tools.

This magnitude is less than unity, and will be closer to unity the more closely the calculated number of machine tools C approaches the taken number S . The coefficient of loading is equal to unity (or 100%), when the calculated number of machine tools is not a fraction but a whole number. In this case $C = S$.

It must be sought to bring the magnitude of the coefficient of loading as close

as possible to unity. As already stated, its magnitude for series production in the shop average must be at least 0.85%.

From eq.(135) it follows that the taken or established number of machine tools is

$$S = \frac{T_k}{F_{pm} \eta_{sr}} = \frac{C}{\eta_{sr}}. \quad (136)$$

The coefficient of loading is calculated for individual machine tools and groups of machine tools. For calculating the coefficient of loading of each of the machine tools separately, the elements to be treated must be assigned to the particular tool machines, and the loading of each of the machine tools calculated in hours, after which, by dividing this total number of hours into the actual time fund based on the taken number of shifts of the given machine, we get the coefficient of loading of the machine tool. In this case $S = 1$ in eq.(134).

In addition to the coefficients for the individual machine tools or groups thereof, the general average coefficient of loading η_{sr} for all machine tools of the shop is also calculated. The calculation can be carried out in two ways:

1) The sum of the calculated numbers of machine tools of all types for all shops is divided by the sum of all taken machine tools, that is

$$\eta_{sr} = \frac{\sum C}{\sum S}; \quad (137)$$

2) The sum total of the number of hours of time norms for all machine tools for the entire yearly program is divided by the actual yearly time fund in all shifts of the taken number of machine tools for all shops (eq.(134)), that is

$$\eta_{sr} = \frac{\sum T_k}{F_{pm} \cdot \sum S}. \quad (138)$$

As can be seen from what has been stated, the loading coefficient shows how many machine tools are loaded by the given work. However, this coefficient does not show

the degree to which the machine tool is utilized for actual machine work, that is, the degree to which it is utilized in comparison with its rated capacity.

The coefficient of utilization of the machine tool on the basis of time η_o for series and individual production is expressed by the formula

$$\eta_o = \frac{T_o}{T_k}, \quad (139)$$

where T_o is the basic technological time in hours;

T_k is the piece-calculated time in hours.

The utilization coefficient of the machine tools on the basis of time is calculated for individual machine tools, for groups of machine tools, and for a general average of all machine tools of the shop.

The average coefficient of utilization on the basis of time for all machine tools of the shop is determined by the ratio of the sum of the basic times to the sum of the calculated times of all the machine tools of the shop, that is

$$\eta_{o, \text{av}} = \frac{\sum T_o}{\sum T_k}. \quad (140)$$

As can be seen, the magnitude of this coefficient, because it enters into the calculated time which is the denominator in the formula, depends on the magnitudes of the auxiliary time, the time for servicing the working place and for physical needs, and the readying-closing time. This means that the smaller the magnitude of this time is, the higher the share of the basic time in the total norm time, and the higher the coefficient of utilization of the machine tool according to the basic time. It must be endeavored in series production to attain an average magnitude of the coefficient of at least 0.60; the greater this magnitude is, the higher the utilization of the equipment.

The coefficients of loading (and also the coefficients of utilization according to the basic time for each of the machine tools or groups thereof) and the average

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coefficients for all machines are entered in the compound bulletin of machine tool loading (Form 6).

The calculated magnitudes of the loading coefficients are represented in the form of a graph constructed according to the coefficients calculated for each of the machine tools separately and for groups of machine tools of the same size. The graph is represented in the form of a broken line or column. In the latter, a separate column is plotted for each of the machine tools, whose full height in the scale used expresses 100%. The percentages expressing the coefficients of loading are laid out on this column. The entire height of the column is divided into as many parts as there are employed shifts. Corresponding to each of the coefficients, the height of the column shows the loadability of the machine tool in relation to the number of shifts used. The graph for the coefficients of utilization of the machine tools according to the basic time is also constructed in a similar manner.

On the graphs for loading (or utilization according to the basic time), in addition to the coefficients for individual machine tools or groups of machine tools, the total average coefficient of loading (or utilization according to the basic time) for all machine tools of the shop is also represented in the form of a straight line passing through all the columns (or through the broken line) at a height corresponding to the magnitudes of the coefficients. Examples of graphs of the coefficient of loading are presented in Figs. 42 and 43 (for Fig. 43 see paste-in at end of book).

B. Determination of the number of machine tools and the coefficient of loading and utilization for flow-mass and flow-series (alternate-series) production according to basic time

The number of machine tools for flow-production (flow-mass and flow-series) is determined on the basis of the time necessary for executing the individual operations. For these forms of production it is necessary to attain synchronization of operation corresponding to the rhythm necessary for the creation of continuous flow used. For this purpose the whole process is divided into individual operations identical as

nearly as possible (in slow rhythm) or repeated with respect to the time for their execution.

For attaining synchronization of operations, that is, bringing the operational time into correspondence with the rhythm, various technical and organizational meas-

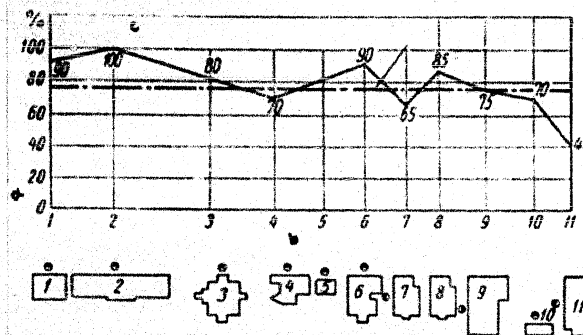


Fig.42 Graph of Machine Tool Loading (According to Time)

a) loading of machine tool; b) machine tool number; c)
average coefficient of loading $\eta_{br} = 76.5$

ures can be taken, some of which are as follows:

- 1) Formulation of the most technological construction of the elements, for which purpose it is necessary to maintain their standardization and also their necessary technology;
- 2) Division or combination (consolidation) of operations; the latter is achieved particularly by the use of rotating and multiplace accessories, multi-tool equipping of the machine tools;
- 3) Employment of optimal cutting conditions corresponding to the rhythm of the flow line;
- 4) Maximum shortening of auxiliary time;
- 5) Employment of special cutting tools;

6) Employment of several tools for simultaneous treatment of several surfaces of element;

7) Simultaneous treatment of several elements;

8) Employment of special and multipurpose accessories, rotary tables, etc;

9) Employment of automation of machine tools as much as possible, mechanization and automation of element verification;

10) Employment of special, specialized and aggregate machine tools, taking into account their over-all saving;

11) Mechanization of intermachine transport by the creation of special transport means;

12) Inclusion of aggregates and equipment for other forms of treatment (heat treatment, welding, presses, platers, etc.) in the flow of mechanical treatment of the elements, yielding a continuity of flow in the production of the elements.

In flow-series (alternate-flow) production, to attain operation synchronization, it is necessary to carry out in addition to the above enumerated measures, the following:

1) Division of elements into groups on the basis of similarity of constructive and technological purpose;

2) Formulation of typical technological routes for groups of similar elements;

3) Formulation of typical technological paraphernalia for particular operations, attained by decreasing the number of retoolings.

The number of machine tools necessary for executing the operations in flow depends on the time necessary for executing the given operations (piecework time) and the working beat. Therefore, to determine the number of machine tools for executing one operation, the necessary time (piecework) for its execution is divided by the magnitude of the beat, that is

$$C_0 = \frac{t_{\text{шт}}}{t_r} \quad (141)$$

where c_o is the number of machine tools for executing one operation in the assembly-line;

t_{sh} is the piecework time in minutes;

t_r is the working beat in minutes.

The working beat, that is, the interval of time separating the handling of two successive elements on the assembly-line, is determined according to the formula

$$t_r = \frac{60F_0m}{D} = \frac{60F_0m}{D}, \quad (142)$$

where F_0 is the actual yearly time fund of the machine tool in hours;

F is the nominal yearly time fund of the machine tool in hours;

k is a coefficient taking into account the idleness of the machine tool during reconditioning;

m is the number of working shifts;

D is the number of elements of one kind to be treated in a year on a given assembly-line.

Substituting the value of t_r in eq.(142) in eq.(141), we get the number of machine tools for executing one operation on the assembly-line.

$$c_o = \frac{t_{sh}D}{60Fkm}. \quad (143)$$

The total number of machine tools in the assembly-line for the treatment of the given element (or group of elements in alternate-flow production) is determined as the sum of the numbers of machine tools taken for the individual operations, that is

$$S_n = \sum s_o, \quad (144)$$

where S_n is the total number of machine tools in the assembly-line of treatment;

s_o is the number of machine tools needed for executing one operation in the assembly-line.

0 In flow-series production, for attaining a sufficient loading of the machine
2 tools, an alternate flow line is organized, to which several elements similar to each
4 other in size and construction are assigned. The treatment of such elements proceeds
6 alternately. For one or several days, the treatment of elements of one kind takes
8 place at a given beat; after readjustment of the line, the treatment of a lot of ele-
10 ments of the second kind takes place; after which the line is again readjusted for
12 treatment of elements of the third kind, etc.

14 For treatment in one line, parts are selected for which the readjustment is
16 simple and does not require much time, or parts for which there is not required any
18 readjustment at all.

20 Accordingly, in a given form of work organization, elements of various kinds in
22 different or equal numbers are treated in the course of the year.

24 If at this beat the work in the line for elements of different kinds must be the
26 same, the magnitude of the take is determined according to a formula analogous to
28 eq.(142), in which the total numbers of elements of different kinds put out in a year
30 will be in the denominator, taking into account the expenditure of time for readjust-
32 ment of the line from one element to the other. Then the formula takes the form

$$34 \quad t_p = \frac{60Fkm}{D_1 + D_2 + D_3 + \dots + D_n} \cdot k_n. \quad (145)$$

36 where $D_1 + D_2 + D_3 + \dots + D_n$ are the numbers of different elements treated in a
38 year in the given line;

40 k_n is a coefficient taking into account the expenditure of
42 time for readjusting the lines from one part to another.

44 If, in an alternate-flow line, the treatment of different elements is to occur
46 at different beats, then the calculation of the working beat must occur separately
48 for each type of element, starting with the time segment during which the given lot
50 of elements must be treated.

52 The loading coefficient of the machine tools in mass-assembly and flow-series
54
56
58

production is determined for the individual operations in the treatment of the given elements, that is, for the given machine tool, and as the average magnitude for the machine tools of the whole assembly line of given elements.

The loading coefficient of machine tools for a given operation equals the ratio of the calculated to the actual number of machine tools needed.

On this basis, the loading coefficient of machine tools for individual operations on given elements will be according to the former denotation

$$\eta_{o.s} = \frac{c_o}{s_o} \quad (146)$$

or, according to eq.(141)

$$\eta_{o.s} = \frac{t_{cht}}{t_p s_o} \quad (147)$$

From this it is apparent that the taken or established number of machine tools for executing the given operation in assembly is

$$s_o = \frac{t_{cht}}{t_p \eta_{o.s}} \quad (148)$$

The average loading coefficient of machine tools for the entire assembly-line is

$$\eta_{n.s} = \frac{\sum c_o}{\sum s_o} = \frac{C_n}{S_n} \quad (149)$$

where C_n is the sum of the calculated number of machine tools for the execution of all operations in assembly, and S_n is the sum of the numbers of machine tools taken for the execution of these operations.

In mass-assembly production, the average loading coefficient of machine tools can be lower than for the usual series production. This is due to the fact that in mass-assembly production, for maintaining continuity of flow in sequential execution of technological operations, some of the machine tools are insufficiently loaded,

and loading them with other elements is impossible because the machines are adjusted for the execution of particular operations. However, despite this, the total output of products by one machine tool is higher in mass-assembly, as also in flow-series production than in the usual series production.

The magnitude of this coefficient must be at least 0.75 and as close as possible to unity; the greater its magnitude is, the more effective is the utilization of the equipment.

As already noted, what is of concern here is the fact that the degree to which the machine tool is utilized directly for machine work is determined by the coefficient of utilization of the machine tool according to the basic time.

The coefficient of machine utilization with respect to base time is defined, for the individual operations of a production line by the formula

$$\eta_{op} = \frac{t_o}{t_{bas}}, \quad (150)$$

and the mean coefficient of utilization with respect to base time of all machines in a production line is defined by the formula

$$\eta_{o.s.r.s} = \frac{\sum t_o}{\sum t_{bas}} = \frac{T_o}{T_{bas}}, \quad (151)$$

where T_o is the sum of base time for all the operations in the production line;

T_p is the sum of piecework time for all the operations in the production line.

Every effort should be made to maximize the value of this coefficient. For this purpose the auxiliary time, the time for service of the work position, and the time for rest and physical needs included in the piecework time must be held down to the lowest possible levels. The higher the value of this coefficient the higher is the direct utilization of the machines for machine work. In assembly-line production, this quantity should on the average not be less than 0.70.

The coefficient of utilization of the machine tool according to the basic time

100

1

0 use of special accessories, mechanisms and machine tool automation. Accordingly,
 2 also in flow-series production, the coefficient of utilization of the machine tools
 4 in relation to the basic time is greater than in series production, which makes the
 6 output of products per machine tool greater. Nevertheless this coefficient will still
 8 be lower in alternate-flow than in mass-assembly production, because the readjustments
 10 of the line to the treatment of elements of different lots cannot be avoided.

12 On the basis of the loading table of the machine tools which is formulated, as
 14 already stated, according to the given technological chart, a bulletin of the mach-
 16 ine equipment with characterization of each of the machine tools (Form 7) is prepar-
 18 ed. In this bulletin, the names of the tool machines, their principal dimensions,
 20 type and mark, the builder, the space requirements, the kind of drive, the power of
 22 the electric motor, the weight, the cost of the machine tool including the cost of
 24 transportation and installation are entered.

26 C. Determination of the number of machine tools according to the technic-economic
 28 indices

30 This method, as already stated, is employed in the planning of enlargements: in
 32 the formulation of projected tasks, the planning of mechanical shops for individual
 34 and small-series production when the production is diverse and its list cannot be
 36 precisely established in advance, in the planning of tool and reconditioning-mechani-
 38 cal shops, and in all cases where the calculation of the approximate number of mach-
 40 ine tools necessary is permissible.

42 This method has great practical worth in the planning of shops and works parti-
 44 cularly when the time for planning the construction and expansion of production is
 46 limited.

48 The accuracy of the results of the calculation according to this method may be
 50 fully sufficient for practical purposes; depending mainly on the correctness of the
 52 indices. With the help of a system of verified indices, the calculation of machine
 54 tools, the number of workers, and in general the whole calculation and planning of
 56

the shop as a whole can be considerably simplified and shortened.

As the basis for calculating the number of machine tools the following technical indices may be used:

- 1) The yearly output from one machine tool working for one shift (or for several shifts) in money expressed in roubles;
- 2) The yearly output from one machine tool working for one shift (or for several shifts) in tons or pieces of finished production;
- 3) The number of machine hours necessary for the treatment of a set of elements of one product or per ton of products or for the driving engine in the treatment of a set of elements in hp.

The accuracy of the enlargement calculations as a whole depends on the correctness of the magnitudes of the indices selected for the purpose. The indices should be based on the practices of the most advanced works, confirmed by recently planned works, analogous or similar in conditions to the one to be planned, including the character of the product, the type of production, the size of the output, the particularities of the technology, etc. For verification of the enlargement calculation of the amount of necessary equipment, it is advisable to operate simultaneously with two-three indices. In view of inconstancy of the criteria (yearly output in roubles from one tool machine in one shift) depending on a number of different and at the same time variable productions and other factors, the necessary number of machine tools calculated with their help must be compared with the results of calculations made on the basis of other indices.

For many machines the average yearly output from one machine tool in one shift is 30-35 tons of finished product, and the number of machine hours expended on the production of one ton of finished product is 80-65.

In Tables 7 and 8 some examples of the number of machine hours expended on the mechanical treatment of one set of elements of heavy and light automobiles and tractors are presented, and in Table 9 some examples of the number of machine hours ex-

Table 7

Examples of Number of Machine Hours in Mechanical Treatment of One Set of
Parts for Heavy and Light Automobiles (in Mass-Assembly Production)

Parts for Heavy and Light Automobiles (21)					
Type of Automobile	Number of Machine Hours				For the Whole Set of Parts for One Automobile
	By Shops				
	Chassis	Engine	Gear box	Trans- mission	
Truck with loading capacity:					29.9
1.5 tons	13.3	8.2	4.9	3.5	30.5
2.5 tons	13.4	10.0	3.6	3.5	57.2
3.5 tons	23.4	17.5	10.3	6.0	121.7
5.7 tons	46.0	42.0	22.0	11.7	
Passenger automobile, light- weight:					31.8
4-seater	13.2	7.4	6.0	5.2	33.0
5-seater	16.0	9.1	4.5	3.4	29.7
Passenger automobile, 5-seater	10.5	9.2	5.0	5.0	

Table 8

Examples of Number of Machine Hours in Mechanical Treatment of One Set of
Parts for Tractors (in Mass-Assembly Production)

Parts for Tractors (in Mass-Assembly)				
Type	Number of Machine Hours			For Whole Set of Parts for One Tractor
	By Shops			
	Chassis (including gear box)	Engine	Transmission	
Transport, caterpillar diesel	97 56	44 36	15 8	156 100
Agricultural, kerosene				
Agricultural, caterpillar, diesel	49.5	30.3	10	89.8
Cultivator, wheel, kerosene	42	28	6	76

Note: The machine hours for the fabrication of the elements of the starting motor and the fuel apparatus do not enter into the number of machine hours for diesel engines.

pendent on the mechanical treatment of one ton of treated parts and output in tons referred to unit production equipment for various forms of machine building.

Table 9

Example of Number of Machine Hours Expended on Mechanical Treatment of One Ton of Treated Elements and Output in Tons According to Unit Production Equipment for Various Forms of Machines

Name of Machine	Number of Machine Hours per Ton Treated Parts	Output per Unit Production Equipment in Tons
Truck, loading capacity 2.5 tons	33.7	94
Chassis shop	23.3	115
Engine shop	87.0	31
Gear box shop	267.0	11.7
Transmission shop		
Passenger automobile	76	28.3
Chassis shop	62	37.8
Engine shop	225	10.4
Gear box shop	425	6.8
Transmission shop		
Caterpillar agricultural diesel tractor 35 hp	35	68
Tractor shop	55	42
Engine shop	190	10.8
Starting motor shop	457	5.1
Fuel apparatus shop	183	15
Transmission shop		
Machine-tool building	161.2	18.9
Grinding machines	192.0	14.5
Gear-cutting machines	162.0	17.5
Automatic lathes	59.3	58.5
Heavy lathes and other machine tools		
Heavy machine building	36	130
Rolling equipment	39	83.3
Equipment for blast furnaces and steel-casting shops	14.5	278
Heavy presses	29.5	102
Bulldozer equipment		

Generally speaking, for heavy machines having a considerable weight, the output from the machine tool in tons will be comparatively greater and the number of machine hours per ton smaller, while for small machines, or machines with a large number of small elements requiring treatment on machine tools, the output from the machine tool

in tons will be smaller and the number of machine hours per ton greater.

Knowing, according to the production task, the weight of the finished products (or the number of pieces of the same product) put out in a year, and the index determined by the yearly output from the machine tool in tons (or pieces) at work for one shift, we get the calculated number of machine tools.

If C is the calculated number of machine tools;

Q is the weight of the finished products put out in a year, in tons;

q is the yearly output in tons of finished products (index) from one machine tool working for one shift;

m is the number of working shifts of the machine tool,

then

$$C = \frac{Q}{qm} \quad (152)$$

The calculated number of machine tools according to the index expressing the number of machine hours expended per ton finished products can be determined according to the formula

$$C = \frac{T}{F_{\delta} m} = \frac{hQ}{F_{\delta} m} \quad (153)$$

T is the total number of machine hours of the whole yearly program;

h is the number of machine hours expended per ton finished products (index);

F_{δ} is the actual yearly time fund of the tool machine in hours for work in one shift.

Since the coefficient of loading of the machine tool is

$$\eta_s = \frac{C}{S}$$

therefore the taken number of machine tools according to formulas (152) and (153)

$$S = \frac{Q}{qm\eta_s} \quad (154)$$

$$S = \frac{nQ}{F_{\delta} m \eta_s} \quad (155)$$

From this formula it follows that

$$\frac{1}{q} = \frac{h}{F_{\delta}} \quad (156)$$

$$q = \frac{F}{F_{\delta}} \quad (157)$$

$$F_{\delta} = qh \quad (158)$$

In the calculation of the number of tool machines according to formulas (154) and (155), the magnitude of the coefficient of loading n , may be taken at 0.85. The taken general number of machine tools calculated for all shops (according to formulas (154) and (155)) is distributed by types in percentages on the basis of the data of existing mechanical shops of the corresponding branch of machine-building.

The number of machines of each type obtained in this way, if a fraction, is rounded to a whole number in one or the other direction, but in such a way that the number of machines is within the limits of the taken number. For such rounding of fractions, the character of the machines enabling the same treatment must be taken into account.

The further, more detailed distribution of machine tools by types and sizes in each of the groups occurs on the basis of the largest and characteristic elements of planned production. In the absence of necessary data the machine tools are selected by analogy with existing shops of advanced works in the given branch of machine-building.

As the result of executed calculations and selection of the types of machine tools, a bulletin of the machine equipment (according to Form 7) is prepared with

Table 10

Name of Machine Tool	a	b	c	d	e	f	g
Lathes	25.3	37.2	24.1	56.95	14.5	21	40-45
Multicutter	-	-	-	-	2.66	4	
End lathes	2.3	-	-	-	1.56	-	
Relieving lathes	6.7	20.66	0.9	7.33	25.4	4	
Turret machines	1.8	-	-	-	2.47	-	
Automatic machines	2.8	3.19	8.7	4.89	6.48	-	20-15
Vertical machines	3.7	7.33	18.5	6.1	0.6	1.5	
Horizontal boring machines	-	-	-	-	-	-	
Drilling machines (vertical, radial, horizontal)	11.2	9.79	9.62	5.8	21.92	13	
Longitudinal planing machines	8.8	0.7	17.73	3.52	-	3	
Transverse planing machines	7.4	3.03	1.24	4.58	-	1.5	10-15
Slotting machines	1.7	1.19	3.98	1.22	-	-	
Broaching machines	-	-	-	-	0.44	1.5	
Milling machines (universal, horizontal, vertical, longitudinal, transverse, splining, threading, etc.)	12.9	9.15	6.71	2.75	14.2	16	
Gear-cutting machines	-	0.33	7.55	6.56	1.7	12.5	
Grinding machines (round, flat, longitudinal, inner-vertical, planetary, centerless, etc.)	3.8	1.94	0.48	-	4.25	12.5	5
Special	7.8*	2.1***	0.37	-	0.37	7.5	10
Miscellaneous	3.8**	3.39	0.12	0.3	3.45	2	
Totals	100	100	100	100	100	100	100

*Includes lathes for semi-inclines, tires, treatment of axles, boring of cylinders, bearing axles, wagon poles, portal-milling-slotting machines for frames, mill machines for bearing axles, coulisses, crossheads, two-spindle grinding machines for wagon poles, etc.

**Includes bolt-cutting, nut-cutting, pipe-cutting, straightening-calibrating, edge-planing machines, eccentric presses, bending, expanding machines, disk saws, centering machines, press-shears, etc.

***Includes special machines for crankshafts, for boring connecting rods.

Components of Equipment in Mechanical Shops in an Entire Complement of Machine Tools in %

a - Steam locomotive type CO; b - Portable engines 20 hp; c - Average-sort rollingmills weight 1750 tons; d - Electric bridge cranes 5 tons; e - Highspeed diesels 5-40 hp; f - Lathe-screwcutting machines 1D63A; g - Average enlargement according to statistical data of machine-building works

Table 11

Composition of Equipment in Mechanical Shops for Automobile Works (in %)

continued

Table 11 continued

1. Name of equipment; a - Lathes simple; b - Lathes multicutter one-spindle semiauto-
 matic; c - Lathes multispindle multicutter semiautomatic; d - Automatic machines;
 e - Special lathes; f - Turret machine; g - Vertical machines; h - Vertical drilling
 machines one-spindle; i - Vertical drilling machines; j - Special aggregates for
 drilling, boring and thread-cutting; k - Radial drilling machines; l - Diamond drill-
 ing machines universal and special; m - Milling machines horizontal and universal;
 n - Milling machines vertical and splining; o - Longitudinal milling machines;
 p - Vertical drilling machines; q - Special drilling machines; r - Thread-milling
 machines; s - Broaching machines; t - Bolt-cutting, thread-cutting, thread-generating
 and nut-cutting machines; u - Round-splining machines; v - Special grinding machines;
 w - Centerless-grinding machines; x - Inside-grinding machines; y - Flat-grinding
 machines; z - Honing, polishing, superfinishing and lapping machines; aa - Gear cut-
 ting machines; ab - Others; ac - Totals; 2. Chassis shop; a - Heavy machines; I. 1.5-
 2.5 tons; II. 3-3.5 tons; III. 5-7 tons; b - Light machines; 3. Engine shop;
 a - Heavy machines; I. 1.5-2.5 tons; II. 3-3.5 tons; III. 5-7 tons; b - Light mach-
 ines; 4. Gear-box shop; a - Heavy machines; I. 1.5-2.5 tons; II. 3-3.5 tons; III. 5-
 7 tons; b - Light machines; 5. Transmission shop; a - Heavy machines; I. 1.5-2.5
 tons; II. 3-3.5 tons; III. 5-7 tons; b - Light machines

characterization of each machine tool.

Table 10 contains the composition of the equipment in mechanical shops (in per-
 centages of all machine tools of the shops) according to the planning data on some
 machine-building works and the average percentual ratios of machine-tool types ac-
 cording to the statistical data of a number of machine-building works.

In Tables 11 and 12 the compositions of the equipment of the mechanical shops
 for the production of various types of automobiles and tractors with a more differ-
 entiated distribution of machine tools by type are presented.

Table 12

Name	1		2		3	
	a	b	a	b	a	b
Lathes simple	4.5	5.5	3.5	4.5	2.5	1.75
Lathes multicutter semiautomatic	11	11	11	10.5	-	-
Multispindle multicutter semiautomatic	0.5	2.5	2.5	2.5	-	-
One-spindle and multispindle automatic	-	-	0.75	0.75	43	51
Special lathes	-	-	0.75	0.75	-	-
Turret machines	7	6.5	3.5	4.5	6	4.5
Vertical machines	1.75	0.75	0.75	0.75	-	-
Vertical drilling machines one-spindle	11.0	14.5	14.0	12.0	13	15
Vertical drilling machines multispindle	4.5	5.5	3.0	3.5	-	-
Special aggregated drilling, boring and thread-cutting machines	4.5	4.5	6.5	9.0	-	-
Radial drilling machines	6.5	4.25	4.5	4.5	-	-
Universal boring machines	0.25	0.25	-	0.25	-	-
Diamond boring machines universal and special	-	0.5	1.75	1.75	-	-
Horizontal and universal milling machines	5.5	4.5	9.0	7.0	8	8
Vertical and spindle milling machines	3.5	1.5	1.5	1.5	-	-
Longitudinal milling machines	1.75	3.25	0.5	2.25	-	-
Vertical milling machines	-	0.25	0.25	0.25	-	-
Special milling machines	0.25	1.5	1.5	1.25	0.5	0.5
Broaching machines	2.5	3.0	1.75	1.75	-	-
Thread-milling machines	1.75	1.75	1.5	0.75	0.5	0.5
Slotting machines	0.5	0.25	-	0.25	-	-
Bolt-cutting, thread-cutting, thread-generating, nut-cutting machines	0.75	0.75	0.75	0.75	9	7.5
Round-grinding machines	3.4	4.5	4.5	3.5	3	2.5
Special grinding machines	0.25	0.25	1.5	1.75	-	-
Centerless-grinding machines	0.25	0.75	2.5	2.5	3	2.5
Inside-grinding machines	2.0	1.5	0.75	0.25	-	-
Flat-grinding machines	0.75	0.75	3.5	2.5	1.5	1.5
Honing, polishing, lapping, superfinish-ing machines	0.5	0.5	2.5	1.5	1.5	1.5
Gear-cutting machines	17	14.5	1.75	1.75	-	-
Other equipment	7.75	4.75	13.75	10.5	8.5	3.25
Totals in %	100	100	100	100	100	100

Composition of Equipment in Mechanical Shops of Tractor Works (in %)

1. Tractor shop including gear-box shop; a - Wheeled tractors; b - Caterpillar tractors; 2. Engine shop; a - Wheeled tractors; b - Caterpillar tractors; 3. Transmission shop; a - Wheeled tractors; b - Caterpillar tractors

20. Worker Composition of Shops and Determination of Their Numbers

The total number participating in the work of the shops is composed of:

- a) Productive workers, principally machinists;
- b) Auxiliary workers;
- c) Younger service personnel (MOP);
- d) Service: engineer-technical workers (ITR) and accounting-office personnel (SKR).

For series and individual production, the determination of the number of productive workers - machinists, according to the type of work (specialties) and according to the qualifications (classes) may occur in two ways:

1. According to the total time norm necessary for the production of the number of products per year;
2. According to the given number of machine tools.

According to the first method, the number of workers - machinists is determined on the basis of the sum of the piece-calculated times for each of the operations entered in the technical chart according to the formula

$$R_{st} = \frac{T_k}{F_{d,r} s_r} = \frac{\sum t D}{60 F_{d,r} s_r} \quad (159)$$

where R_{st} is the number of workers - machinists;

T_k is the sum of the standardized piece-calculated times necessary for treatment on machine tools of a given type of the number of elements (including spare parts) in hours per year;

$F_{d,r}$ is the actual time fund of the workers in hours per year;

s_r is the number of machines on which one worker can work simultaneously (coefficient of multimachine tending);

t_k is the piece-calculated time for the treatment of one element in minutes.

D is the number of identical elements treated in a year on the machine tool of a given type-size.

For the calculation of the number of machine workers in series and individual production, the calculated time is employed as stated above because in these forms of production, the readying and adjustment of the machine tools and other readying-closing manipulations are carried out partly or wholly by the machine workers themselves. As already stated, the magnitude of the readying closing time entering into the calculated time is small in large-series production but considerable in small-series and individual production.

According to the second method, that is, according to the number of machine tools, the number of working machinists is determined on the basis of the given or taken number of machine tools S.

From formula (134)

$$\eta_0 = \frac{T_s}{F_{\delta} m S},$$

determining the magnitude of the coefficient of loading of the machine tools, it follows that

$$T_s = F_{\delta} m S \eta_0. \quad (160)$$

Substituting this value of T in formula (159) we get

$$R_{st} = \frac{F_{\delta} m S \eta_0}{F_{\delta, r} s_r}. \quad (161)$$

If the number of working machinists obtained by calculation according to formulas (159) and (161) is a fraction, it must be rounded to a whole number. Instead of rounding a small fraction, the combined work of various trades must be used as much as possible.

For the calculation of the number of working machinists according to formula (161), it is necessary to know the magnitude of the coefficient of loading of the machine tools. If it is unknown, it may be taken at $\eta_0 = 0.85 \div 0.90$.

The actual yearly fund of working time equals the nominal yearly time fund minus the excusable absentee time.

In planning, the excusable absentee times are taken in established amounts.

The nominal yearly fund of working time F_r is determined on the basis of the calendar-year number of days (365) minus holidays (6), vacation (12) and days of rest (52). For the stated yearly number of days, the nominal yearly time fund is 295 days or 2360 hours - in an eight hour working day for the first and second shifts (for the workers of the third shift - 2065 hours at seven hours of work per shift).

The actual (calculated) yearly fund of working time $F_{g,r}$ is obtained by multiplying the nominal yearly time fund by the coefficient k_r , taking into account the excusable absentee time ($k_r \approx 0.96 \div 0.97$ in the above calculation of the nominal yearly fund). On the basis of the foregoing, the actual (calculated) yearly fund of working time $F_{g,r}$ in planning is taken at 2260 hours for the workers of the first and second shifts (for the third shift at 1980 hours).

For improving the utilization of the working force for incomplete loading of machine tools, it is advisable where possible to introduce multimachine tending work, for example, on automatic machines, gear-cutting machines, roughing lathes, planing machines, etc.

From the foregoing considerations it follows that for attaining full utilization of the working time, the calculation of the number of machinists must occur according to formulas (159) or (160), taking into account the magnitude of n , obtained according to the calculation of the machine tools.

In flow production (assembly-line) the number of working machinists is determined according to the number of working places (machine tools) carrying out the particular operations if the machinists work on one machine each. In this case the utilization of the working time will correspond to the load of the working places (machine tools), which must be as close as possible to the magnitude of the beat.

In multimachine work, if it is possible according to the operation carried out,

the number of machine tools which can be tended simultaneously by one worker is determined by calculation, and as is more frequently done, by the use of experimental data on multimachine work.

If the machine tools are identical, and the operation is one and the same, their number can be calculated according to the formula

$$c \leq \frac{t_m}{t_{v,r} + t_{per}} + 1, \quad (162)$$

where c is the calculated number of machine tools which can be operated simultaneously by one worker;

t_m is the uninterrupted machine time on one machine (the time during which the machine tool operates without direct participation of the worker);

$t_{v,r}$ is the auxiliary manual working time expended on one machine tool;

t_{per} is the time expended on the work of transition from machine tool to the other and on the servicing of the machine tool before starting it.

If the calculated number of machine tools is obtained with a fraction, the fraction is eliminated; the obtained number is called the taken number of machine tools s_r .

If the machine tools tended by one worker are identical, and carry out one and the same operation, then their t_m values are equal. If however the machine tools are different, or if they are identical, but carry out different operations, then the t_m of the machine tool with which it is smaller must be taken for the calculation.

From formula (162) it can be seen that for simultaneous work on several machine tools, the uninterrupted machine time of one machine tool must be fully included in the time expended by the worker for manual manipulations on other machine tools, for standing at the machine tools, and for changing from one machine to another. For precise ascertainment of the possibility of such combined work it is necessary to prepare, on the basis of an analysis of the technological processes on the combined

machine tools, a cyclogram of the work according to its components. These cyclograms determine the sequence of tending the machine tools, the times expended by the worker for working on each machine tool, and the period of uninterrupted time on one machine tool.

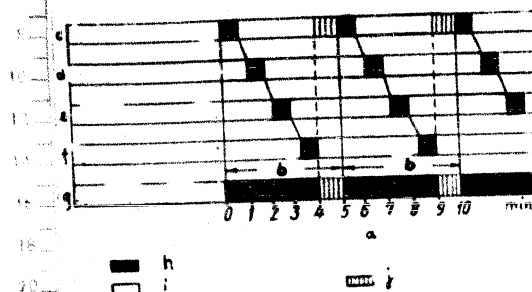


Fig. 44 Cyclogram of Simultaneous Working on Four Machine Tools

a - Time in minutes; b - Cycle; c - Time of 1st machine; d - Time of 2nd machine; e - Time of 3rd machine; f - Time of 4th machine; g - Working time; h - Auxiliary and transition working time; i - Machine time; j - Free time to the other.

Simultaneous operation of several machine tools is easier to realize on machine tools most completely automated, by which the auxiliary time is brought to a minimum, and by which the manual manipulations are eliminated or reduced to a minimal number. Consequently, for enabling one worker to work simultaneously on several machine tools of the universal type it is necessary to equip the machine tools with suitable accessories, stops, auto disconnectors and other devices and appurtenance shortening the time and eliminating the necessity of manipulations by the worker.

For working on two or more machine tools, their relative location must be such that the expenditure of time on changing from one machine tool to the other is mini-

An example of a cyclogram for simultaneous operation of four machine tools is represented in Fig. 44.

The selection of the machine tools on which one worker can work simultaneously depends on the character of the technological operations, the ratio between the components of the expended time, the uninterrupted machine time, the frequency of manual manipulations and the changes of the worker from one machine tool

mal, and the control mechanism is in easy reach and in the most convenient place.

Some examples of the arrangement of the machine tools are presented below.

Rational organization of the working place, consisting of its necessary preliminary readying, timely and precise tending in the working process, and most modern planning, is an indispensable condition for attaining by multimachine work the most complete utilization of the machine tools and the highest productivity of the work.

The form of the organization for simultaneous work on several machine tools depends on the types of the combined machine tools, the character of the operations to be performed, the character and duration of the auxiliary manipulations; it may be individual or by team. In the individual form only one worker works and fully tends two or more machine tools; in the team form two or more workers work and tend several machine tools, of which all of the workers are masters or one or several workers are masters and the rest of them are helpers.

Simultaneous work on several machines may, depending on the technological operations carried out, occur in various ways:

- a) Parallel execution of one and the same operation on several machines (double machines);
- b) Successive execution of operation on treatment of one and the same element on several machines;
- c) Execution of different operations on different elements on several machines.

In some cases, one of the forms of simultaneous work organization on several machines consists of the dividing of the machines into principal and supplementary (auxiliary) machines. The principal machines are those on which the most important operations are carried out, requiring greater attention and less uninterrupted machine time in comparison with the other machines. On the supplementary machines less important treatments of other elements are carried out with considerable uninterrupted machine time, not requiring constant attention. Accordingly, the work on these machines is supplementary to work on the principal machines.

0 The practical results of simultaneous work on several machine tools obtained in
 2 many advanced works indicate a high technico-economic effect of the multimachine
 4 method of work, which must be introduced as widely as possible into production in the
 6 formulation of technological processes.

8 In the planning of new mechanical shops the number of machine tools on which one
 10 worker can work simultaneously is determined not by detailed calculation but by using
 12 experimental data on multimachine work from the corresponding branch of machine-
 14 building. These data express for various types of machine tools the coefficient of
 16 multimachine tending, that is, the number of machines which can be operated simul-
 18 taneously by one worker.

20 Thus for example, the coefficient of multimachine tending in the planning of
 22 automobile and tractor works is taken at:

24 For multicutter lathes, semiautomatic lathes, large milling
 26 machines..... 1.5-2
 28 For multispindle semiautomatic machines..... 1.2-1.5
 30 For one-spindle automatic machines and gear-planing machines.. 3-4
 32 For gear-slotting and gear-milling machines..... 4-5
 34 For universal lathes, drilling, broaching, turret, milling
 36 (small and medium) round and flat grinding machines, mach-
 38 ines of uninterrupted action (milling, grinding etc. mach-
 40 ines)..... 1

42 In mass-flow production with a precisely determined number of workers at the
 44 working places, the number of machinists is definitely established after formulation
 46 of the equipment, when the possibilities of one worker tending several machines are
 48 ascertained.

50 With the help of formulas (159) and (161), the number of working machinists is
 52 calculated (for series and individual production) according to the type of work (or
 54 specialties) and according to their qualifications (or classes), for which the pos-
 56

sibility of combining various trades is taken into account. This calculation is based on the sum of the times for the individual operations listed in the technological chart.

For calculating the number of machinists according to specialties and classes, a table of the number of working hours for the machinists necessary to produce one machine or the total number of machines in the yearly program is prepared (Form 8). By adding together all of the times for all of the elements, the necessary time (in hours) for the production of one machine is obtained, according to each specialty and each class of worker. By multiplying the latter time by the number of machines in the yearly program, the total time according to specialties and classes necessary for the total number of machines is obtained. To the obtained total time is added the time for the production of the spare parts, if it is not included in the number of elements to one product. If several types of products enter into the program of a shop, individual load time tables by specialties and classes of workers for one machine of each class are first prepared, and then the general table on the total number of machines on the program.

After this, the definite time necessary for carrying out the yearly program is divided by the actual time fund of one worker and the coefficient of multimachine tending (number of machine tools which can be tended by one worker simultaneously) according to eq.(159). As a result, the calculated number of workers are obtained according to each specialty and class, which, if it is a fractional number, is rounded to a whole number. For this a small fraction (> 0.5) must be added to the next higher class ("cooperating") or another specialty ("combined trades"), which gives the possibility of attaining a better utilization of the worker's time. Next, a compound bulletin of all the productive workers of the shop (Form 9) is prepared, in which the number of workers of each class according to all of the specialties (with enumeration thereof), are entered, giving the possibility of calculating the total number of workers of each class. In the same Table the class coefficients,

Form 3

a) Name of element; b) Drawing No.; c) Number of elements to one machine; d) Lathe machinists; e) Turret machinists; f) Planing machinists; g) Slotting machinists; h) Milling machinists; i) Total; j) Total minutes per machine; k) Total hours per machine; l) Total man-hours in yearly program of ... machines on spare parts; m) Total man-hours in yearly production program; n) Total man-hours in yearly program; (if not included in number of elements of yearly production program; o) Cooperating and combined trades;

n) Calculated number of workers $R_{st} = \frac{\Sigma t_{kD}}{60 \cdot \dot{F}_{op}^{st} p} = \frac{T_k}{60 \cdot \dot{F}_{op}^{st} p}$ 1st class; s) 4th class; t) 5th class; u) 6th class

p) Taken number of workers R; q) 2nd class; r) 3rd class; s) 4th class; t) 5th class; u) 6th class

the number of workers of the first class, the average class coefficient, and the average class according to shops are entered. In the form the numbers of workers working in the first, second, and third shifts are also noted.

The number of workers reduced to the first class is obtained by adding together the products of the number of workers of each of the classes times the corresponding wage (class) coefficient; thus, for example, for 79 workers of the 4th class, 20 workers of the 5th class and one worker of the 6th class (total 130 workers), the number of workers reduced to the first class is

$$(30 \times 1.26) + (79 \times 1.41) + (20 \times 1.68) + (1 \times 1.94) = 184.73.$$

The average class coefficient is obtained by dividing the number of workers reduced to the first class by the number of workers of all of the classes of a given specialty; in the above example:

$$184.73 : 130 = 1.42.$$

With the help of the compound bulletin, the average class of productive workers for all of the shops can be established, which is obtained as the average weighted magnitude for all classes of all workers. For this purpose, the reduced number of workers in the respective classes must be added together, and this total divided by the total number of workers; for the above example the average class is

$$[(30 \times 3) + (79 \times 4) + (20 \times 5) + (1 \times 6)] : 130 = 3.94.$$

The average class of qualifications for the productive workers of mechanical shops depends on the form of production: normally, the average class of shops for small series and individual production may be taken at 4.0-4.5, for large series at 3.25-3.75, for mass at 3.25-3.5. The highest class of qualifications is required for automated production - for automatic lines, shops and works.

The number of productive working mechanics in mechanical shops for enlargement calculations is taken in a percentual ratio of the number of machinists: for example,

Form 9

Compound Bulletin of Composition of Productive Workers

a	w	x	o						q	r	s	t	u	v	
			y	z	aa	bb	cc	dd							ee
b															
c															
d															
e															
f															
g															
h															
i															
j															
k															
l															
m															
n															

a) Name of trade; b) Lathe machinists; c) Ditto; d) Turret machinists; e) Milling machinists; f) Planing machinists; g) Drilling machinists; h) Grinding machinists; i) Miscellaneous; k) Markers; l) Mechanics; m) etc.; n) Total; o) Number of workers by classes; p) Class (wage) coefficient; q) Total workers; r) First shift; s) Second shift; t) Number of workers belonging to 1st class; u) Average class coefficient; v) Average class by shops; w) Name of tool; x) Number of appliances; y) 1st; z) 2nd; aa) 3rd; bb) 4th; cc) 5th; dd) 6th; ee) 7th; ff) 8th

for small series and individual production at 3-5%, for mass and large-series production at 1.3%.

For carrying out the auxiliary work in the shops, auxiliary workers are included in the composition of the working personnel. This pertains to machine adjusters, teams (free of work on machine tools) of storeroom men, leather workers, lubricators, tool sharpeners, gaugers (checkers), crane operators, mechanics, machine fixers, electricians, transport and other secondary workers.

The number of workers for each of the specialties is determined on the basis of calculation and practical data, depending on the character and volume of the work to be carried out: adjusters, lubricators, leather workers, electricians, tool suppliers - according to the number of machine tools serviced; crane operators - according to the number of cranes in operation; gaugers - according to the given technological process of checking; tool sharpeners - according to the sharpening machines, taking into account their coefficients of loading (compare further in this Chapter), etc. For this, the possibility of combining the work of various trades must be kept in mind.

Often a detailed calculation of the number of auxiliary workers is not carried out, but this number is taken in a percentage of the number of productive workers on the basis of practical data. The total number of auxiliary workers is preferably divided into two groups: servicing and nonservicing the equipment; the first, approximately 60% and the second, 40% of the total number of auxiliary workers.

In series production, the total number of auxiliary workers in the shops is 18-25% of the number of productive workers; in mass production 35-50%.

Younger service personnel of the shops (MOP): cleaners of shops and recreation rooms, errand runners, telephone operators, make up 2-3% of the total number of workers.

A bulletin of the composition of the auxiliary workers with division according to classes and indication of the class coefficients is prepared analogously to the

bulletin of the production workers.

The shop employees consist of two categories: engineer-technical personnel (ITR) and office-account personnel (SKP). Their total number is 14-18% of the total number of workers, of which the engineer-technical personnel constitutes 10-13% of the total number and the remainder consists of the accounting-office personnel.

The total number of productive workers, auxiliary workers, younger service

Form 10

Compound Bulletin of the Total Composition of Working and Mechanical Shops

Name	Total	By Shifts		In % of Productive Workers	In % of Total Number
		First	Second		
Productive workers					
Auxiliary Workers					
Younger service personnel					
Total					
Clerks					
Of which:					
Engineer-technical workers					
Accounting-office personnel					
Total					

personnel and clerks (called the total number of participants) is brought together in a general bulletin with indication of the percentual ratios of these categories to the total number of productive workers and to the total number of participants of the shops. A specimen of such a bulletin is represented in Form 10.

21. Planning of Equipment and Working Places in Shops

As already stated, the composition of the production department and of the participants of the mechanical shops are determined by the character of the produced

products, the technological processes, the size and organization of the production. In mass-flow production, for example, of autotractors, the shops named according to the aggregates produced, are divided into departments according to the purpose or name of the aggregate produced. The engine has the departments of "cylinder blocks", "crank and camshafts", "connecting rods", etc. The departments are divided into sections according to the names of the elements, for example, the department "cylinder blocks" has the sections "blocks", "valve guide bushes", "main bearing cases", etc.

In series production the mechanical shop is divided into departments (sections) either according to the size of the elements (department of large elements, departments of medium-sized elements, department of small elements) or according to the character and type of the elements (department of shafts, department of gears, department of body details, etc).

The relative location of the departments and sections is determined on the basis of the general components of the shop (on the components of shops, see Chapter XIX "General Components of Shops in One Building").

The metal-cutting machines of the production departments or sections of the mechanical shops may be located in the shops according to two methods: (1) according to equipment; 2) the sequence of technological operations.

According to the first method, which is characteristic of individual and small-series production and of treatment of individual elements in series production, the tool machines are located according to the treatments to be carried out, i.e., sections of lathes, planing, milling, drilling, grinding and other machines are created. The sequence of the location of the sections of similar tool machines on the floor of the shop is determined by sequence of operation on the most important types of elements. Thus, at the start of the production process for elements having the form of a body of rotation (pulleys, couplings, flanges, disks, cogwheels bushes, rolls, pistons, etc) lathes must be located.

For large shafts and other larger elements requiring lathe treatment, a group of large lathes is assigned. Here the face and vertical machines for facing elements of larger diameter, as, for example, flywheels, pulleys, etc may be located. In the adjacent section slotting machines for making keyways in elements may be located.

In the middle of the shop aisle sections of milling machines may be located, in which universal-milling, horizontal-milling, and vertical-milling, and also gear-cutting machines may be placed. Alongside the milling machines transverse planing machines are placed. Radial and vertical drilling machines are also provided. The sections of grinding machines for finishing operations are usually located at the ends of the shop.

For the treatment of flat elements (plates, frames, beds, etc), at the start of the technological flow the layout blocks may be placed, followed by longitudinal-planing and longitudinal-milling machines, then by boring and drilling (particularly radial) machines, and, at the end of the flow, by flat-grinding machines.

In locating the machine tools it must be sought to attain not only straight-flow production but also optimal utilization of the undercrane floor space. For this purpose, all of the machine tools are distributed preferably into several groups depending on the weight of the elements to be treated, and these groups of machine tools are located beneath bridge cranes of suitable loading capacity. The machine tools for treating small and lightweight elements are located on the floor space not served by the cranes.

According to the second method, which is characteristic of shops of series and mass production, machine tools are located in the sequence of the technological operations for the treatment of similar or slightly dissimilar elements having a similar sequence of treating operations. In large-series and mass production such groups (lines) of machine tools carry out the treatment of one kind of element (for example, piston group, connecting-rod group, etc). In small- and medium-series

production each of the groups (lines) of machine tools carries out the treatment of several kinds of elements having an analogous sequence of operations, because it is not always fully possible to load all of the machines with one kind of element.

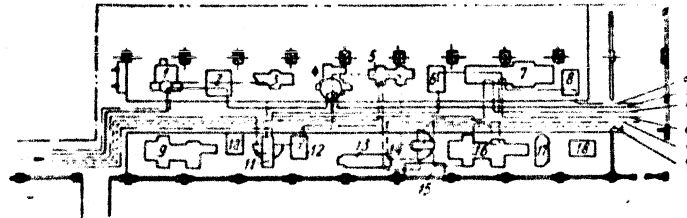


Fig. 45 - Graph of Movement of Elements in a Mechanical Shop

1 - Spline-slotting machines; 2 - Plate for verification; 3 - Face lathe; 4 - Vertical machine; 5 - Boring machine; 6 - Plate for verification; 7 - Longitudinal planing machine; 8 - Plate for verification; 9 - Boring machine; 10 - Plate for verification; 11 - Radial drilling machine; 12 - Plate for verification; 13 - Lathe; 14 - Radial drilling machine; 15 - Testing point; 16 - Boring machine; 17 - Lathe; 18 - Plate for verification

a) Bed; b) Flywheel 2; c) Cylinder 2; d) Lid; e) Cylinder 1; f) Flywheel 1

In locating the tool machines in groups (lines) it is necessary to provide for the shortest path of movement of each of the elements in the process of treatment and not to permit reverse, annular and looping movements, which would create convergence of flows and complicate the transport of the treated elements.

Zigzag movement of the elements in the limits of the same aisle from one row of machine tools to another located parallel with the first one is wholly permissible, because the crane or trolley moving in the one direction is able to deliver elements to the tool machines of either row of the same aisle without any difficulty

also in the reverse direction (an aisle is defined as a part of the building organized in the longitudinal between two parallel rows of columns).

The sequence of passage of the elements between machine tools constitutes the technological line of movement of the elements.

The movement of the elements can be shown on the plan of the location of the equipments (Fig. 45).

Each group (line) of machine tools is placed in a separate aisle or part of the shop (bed aisle, shaft aisle, gear-box department, etc).

Transfer of elements from one aisle to another (interaisle cooperation) for carrying out any operation is undesirable, because it creates difficulties and inconvenience in the transport, and is permissible only in the case of extreme necessity, in the presence of adjacent aisle of incompletely-load machine tools which have to be operated in combination.

For the transfer of elements to another aisle the general straight-flow movement of the elements must be retained.

The transfer of elements between aisles may occur according to the following method (Fig. 46): electric motor or hand trolley 1; rotating crane (rotating derrick) 2; rollway 3; monorail with suspended trolley (electrohoist) 4; bridge crane 5 with rotating boom.

The transfer of elements to another aisle by means of an electro-trolley is permissible when the machine tools to which the elements are transferred are present in the other aisle with a transverse passageway of the shop; in this case at the arrival of the elements in the other aisle the general rectilinear movement of the load is retained. If such a transverse passageway is not provided in the plan of the shop, it must be made especially for the passage of the electro-trolley or other form of transport.

The rotating crane (derrick) with manual or electric tackle is mounted on the columns separating the aisles or on special columns provided for it. The elements

are transferred from the machine tool present in the one aisle to the machine located in the other aisle, by so doing the boom of the crane must be able to service both machine tools.

For the transfer of elements from one machine to the other located in the neighboring aisle by means of a rollway, the latter is placed between these machines in the transverse direction of the aisles.

For transferring the elements by means of a telfer to a machine present in another aisle, a monorail suspension way between the machines served by the telfer is provided.

The transfer of the elements by means of a special bridge crane with rotating boom occurs in the interval between the columns; the rotating crane takes the elements in one aisle, and, turning around, delivers them in the other neighboring aisle.

The sequential location of the machine tools on the plan occurs according to the operation number of each of the elements. For this purpose, the loading table is used, where, in the column for the given machine its load for the treatment of the given element in minutes or hours, is entered, with notation of serial number of the operation whose execution requires the indicated time.

When several different elements are to be treated on the same line of machine tools, the definite locations of the machine tools cannot be noted on the plan immediately, because it is necessary to select optimal locations of them for all of the elements to be treated on them. Accordingly, the space requirements of the machine tools in the corresponding scale, are preliminarily laid on the plan cards (cut out of cardboard) representing in plan, at which the locations of the machine tools are noted on the plan, giving the shortest path of movement of all of the elements to be treated on the given line of machine tools.

For sketching the outside dimensions of a machine tool, its contour at the farthest projecting parts is taken, at which the end positions of the moving parts

enter into the outside dimensions; for turret and automatic machines, for treating elements from rods, the farther projections of the rod enter into the outside dimensions of the machine tool, which gives a better idea of the space requirements and at the same time a simple form of contour of the depicted machine tool. Every type of machine tool can be tentatively depicted graphically. In Fig.47 (compare inlay

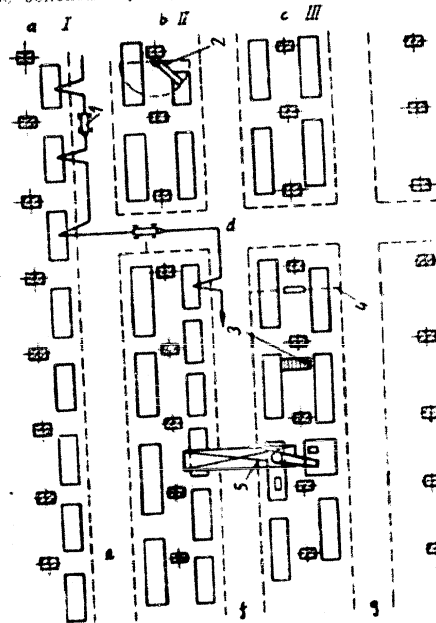


Fig.46 - Scheme of Transfer of Elements between Aisles

- 1 - Electrotrolley; 2 - Rotating crane; 3 - Rollway; 4 - Monorail with crane;
5 - Bridge crane with rotating boom;

a) Aisle I; b) Aisle II; c) Aisle III; d) Transverse passageway;

e) Longitudinal passageway; f) Longitudinal passageway; g) Longitudinal passageway

at end of book) the outside dimensions of several of the more widely employed machine tools in a scale of 1:100 are given (the outside dimensions of the aggre-

gated machine tools of items 53-60 are depicted without observance of this scale).

For the planning of equipment it is always necessary to strive to obtain the shortest possible technological line, so that the elements traverse a linear path. In series production of machines of medium dimensions for the treatment of several elements on each of the lines of machine tools, the normal length of the technological line is 40-60 meters.

After finding the best locations for all of the machine tools of the given line satisfying the sequence of the technological operations on all of the elements, the technological line of movement of these elements is entered on the plan, which furnishes a graphic depiction of a good location of the machine tools. Defects, i.e., deviations from the proper sequence of the technological operations, and mislocations of machine tools, are disclosed immediately upon inspection of the graphs. After making sure of the suitability of the locations for all of the machine tools, their outside dimensions are sketched on the plan in a scale of 1:100, but for very large shops in a scale of 1:200.

Particularly important for increasing the productivity of the work is the rational planning and organization of the working place, in such a way as to eliminate waste walking, waste motion, inconvenient working position, inconvenient location of materials, blanks, tools, etc.

For the treatment of elements in lots, and also for the treatment of elements of larger dimensions, it is necessary to provide room for placing these elements at the machine tool.

Moreover, room for a work table, preferably portable, must be provided at the machine tool, on which the tools are placed, drawings and instruction charts necessary for the work; all of this must be arranged in good order and within easy reach for avoiding unnecessary loss of time. All of the implements must be divided into groups, and each group must have its own place.

For keeping the change gears of the machine tool, pyramids should be used, on

Table 13

Characterization of Metal-Cutting Machines

No.	Name of Machine Tool	Mark (Type)	Base Dimensions in mm	Over-all Dimensions in mm
1	Lathe	161L	175*500	2030*875*1317
2	Lathe-screwcutting machine	162MY	200*750	2365*1318*1340
3	Ditto	1362M	200*1500	3170*1315*1220
4	Ditto	1363	300*3000	5100*1695*1275
5	Semiautomatic multicutter lathe	117	400*1200	4300*1600*2160
6	Ditto	114	300*800	2540*1210*1820
7	Multicutter lathe	1870	430*1580	4963*1840*1500
8	Open-side vertical machine	152	845	2080*2000*3475
9	Single-cutter lathe	173A	200*300	2065*1450*1600
10	Six-spindle vertical semi- automatic machine	1A283	300	2895*2720*3617
11	Single-cutter lathe	1875	430*1910	4963*2150*2080
12	Turret lathe	1336M	38	2280*1000*1280
13	Four-spindle automatic machine	123	36*175	5980*1110*2010
14	Turret machine	136M	63	4420*1425
15	One-spindle automatic turret lathe	1118	18*60	1455*780*1460
16	Ditto	1136	34*90	1800*925*1460
17	Vertical drilling machine	2225	25*175	1150*1110*2320
18	Single-spindle vertical drilling machine	2135	35*340	1210*930*2735
19	Ditto	2150	50*300	1420*930*3040
20	Radial drilling machine	2503	20*1200	1950*870*2135
21	Vertical four-spindle diamond boring machine	117	92*150	2075*1730*3280
22	Horizontal drilling-milling- boring machine	262A	80	4900*2215*2635
23	Horizontal milling machine	680M	225*750	1250*1715*1425
24	Ditto	6082	270*1340	2000*2580*1570
25	Universal milling machine	684	500*1800	2640*3320*1900
26	Vertical milling machine	615	420*1600	2380*2980*2500
27	Longitudinal single-spindle milling machine	6A53	300*1000	2300*1900*1550
28	Two-spindle longitudinal milling machine	6065	450*1250	2580*2680*2080
29	Semiautomatic thread-cutting machine	5B62	Vts200	2660*1200*1350
30	Semiautomatic gear-cutting machine	5301	100*1	1160*640*1460
31	Ditto	5U34	300	2225*1025*1560
32	Semiautomatic gear-shaping machine	5A12	200*4	1240*1030*1730

Table 13 cont'd.

No.	Name of Machine Tool	Mark (Type)	Base Dimensions in mm	Over-all Dimensions in mm
33	Gear-planing machine	524	165*6	1620*1360*1420
34	Machine for rounding faces of teeth	558	450	-
35	Centerless-grinding machine	3180	5*75	2265*1650*1620
36	Round-grinding machine	3416	250*1500	3840*1930*1500
37	Ditto	342A	400*1100	4250*2760*1750
38	Inside-grinding machine	3250	40*200*125	2500*1775*1470
39	Thread-grinding machine	586	120*500	2200*1350*1400
40	Flat-grinding machine	371K	770	2225*1250*2615
41	Ditto	SK371	200*600	2500*1590*1950
42	Flat-grinding machine with rectangular table and hori- zontal spindle	372	300*750	2850*1880*2010
43	Slot-grinding machine	352	140-1000	3250*1650*1600
44	Sharpening machine	3A64	765	3580*2090*2560
45	Flat-grinding machine	371L	830*3035	7000*2920*2450
46	Longitudinal planing machine	713 (2PS)	700	2830*1750*1750
47	Transverse planing machine	736	165	1890*1400*2130
48	Slotting machine	741M	710	1850*1010*1600
49	Disk saw	862	10*38	1630*830*4300
50	Bolt-cutting machine	507	150*1500	2940*800*1250
51	Centering machine	283A	10	5920*790*1250
52	Horizontal-broaching machine	751D		
53	Two-way 44-spindle drilling machine	A125		
54	Three-way 65 spindle drilling machine	A124		
55	Two-way 11-spindle drilling machine	1A201		
56	Three-way 11-spindle drilling machine	A211		
57	Four-spindle vertical-boring machine	A120		
58	Two-way 9-spindle three- cutting machine	A251- 252		
59	Three-way 41-spindle drilling- boring machine	1A198		
60	Three-spindle horizontal- boring machine	A129		

which the wheels are laid in such a way that their dimensions decrease upwardly.

It should be borne in mind that the more rational the arrangement of the working place, the smaller the nonproductive loss of time at working will be.

It should be noted, in particular, that the organization of the working place must assure uninterrupted working; therefore, besides rational planning, it is necessary to eliminate every cause of nonproductive expenditure of time and idleness for various reasons because of untimely delivery of materials, delayed adjustment of the machine tool, absence for delay of tools, inspection, verification and repairing of equipment, etc. It is only under these conditions that full utilization of the equipment and the highest productivity of the work can be attained. Proper planning of the working place, the necessary readying and servicing thereof, are the main factors for increasing the productivity of the labor.

For the formulation of the plan of the location of the machine tools, their locations should be coordinated relatively to the columns; in this way the possibility of precisely determining the place of each machine tool is obtained, regardless of the locations of the neighboring machines. To the columns of each of the aisles a number is assigned. The distance from the given column in two directions determines the location of the machine tool in the shop.

This method of coordination of the location of each of the machine tools creates considerable convenience for the installation of a new shop, when the equipment arrives at different times, and each machine tool is installed in its own place regardless of the arrival of the other neighboring machine tools. This method of determining the places of the machine tools is also convenient with a working shop.

For the depiction of the columns on the plan, their bases should be shown in dotted lines.

For locating the machine tools, it is necessary to be guided by the normal dimensions of the intervals (breaks) between the machine tools in the longitudinal and transverse directions and the distance from the wall and columns. These dimen-

sions must guarantee convenience for execution of the work on the machine tools, safety of the workers, sufficient freedom of movement of persons and transport means with load.

The intervals between the machine tools and the structural elements of the building (columns, walls, etc) are regulated by the rules on the safeguarding of labor and convenience of operation of the machine tools.

Moreover, the provision of a minimal clearance of the machine tool from the column is necessary for avoiding location of the machine tool on the basis of a column having a greater space requirement than the column, and also for having the possibility of delivering the elements to the machine with a crane whose hook can come to within only a certain distance of the column (compare Chapter XVIII).

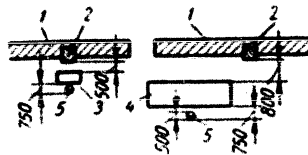


Fig. 48 - Clearance from Projecting Column or Wall for Small, Medium and Large Machine Tools when Workers are Present outside Interval between Machine and Wall
1 - Wall; 2 - Column; 3 - Small or medium-sized machine tool; 4 - Large machine tool; 5 - Working place

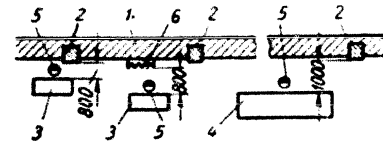


Fig. 49 - Clearance from Wall for Small, Medium and Large Machine Tools when Worker is Present between Machine Tool and Wall
1 - Wall; 2 - Column; 3 - Small or Medium Machine; 4 - Large machine; 5 - Working place; 6 - Heating battery

For the planning of the equipment the following minimal intervals may be used, bearing in mind that:

- a) The indicated clearance from the ends of the moving parts of the machine

tool

b) relates to small machine tools having over-all dimensions up to 750x1500 mm and to large machine tools having one of its over-all dimensions greater than 3500mm.

1. A working place of width 750 mm is provided on the floor in front of the machine tool. The working place for the machine in operation is denoted on the plan by a circle of 500 mm diameter, half of which is hatched or blackened; at this the open part of the circle, which denotes the person of the worker, must be turned toward the machine tool (Fig.48)

2. For placement of a machine tool along the wall, the minimal between the machine tool and a column present in the wall or the projecting part of the wall must be:

a) For location of the worker outside the interval between wall and machine tool (clearance between back side of machine tool and wall): for small and medium

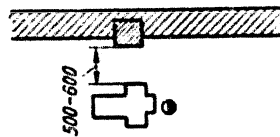


Fig.50 - Clearance from Lateral Side of Machine Tool to Column

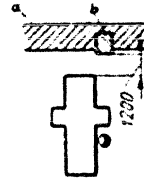


Fig.51 - Clearance from Projecting Part of Wall to Longitudinal-Milling and Longitudinal-Planing machines at their Placement Perpendicular to Wall

a) Wall; b) Column

machine tools 500 mm, for large ones 800 mm (Fig.48).

b) For location of worker between machine tool and wall: for small and medium machine tools 800mm, for large ones at least 1000 mm (Fig.49)

c) Clearance from lateral side of machine tool to wall: for small and medium

machine tools 500 mm, for large ones 600 mm (Fig.50).

3. For the placement of machine tools with moving parts (longitudinal planers, longitudinal millers) perpendicular to the wall the clearance between the wall or the projecting part of the machine at its farthest point must be at least 1200 mm (Fig.51).

4. For the location of machine tools along columns the minimal clearance between column and machine tool must be:

a) For longitudinal-planing, transverse-planing and gear-cutting machines -

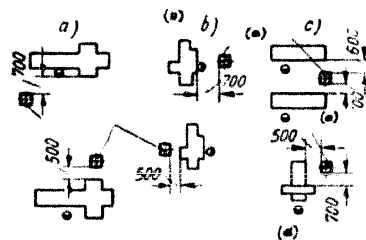


Fig.52 - Clearance between Tool Machine and Column:

- a - For longitudinal planing machines;
- b - For transverse-planing and gear-cutting machines; c - For lathes;
- d - For milling and grinding machines

a) Column

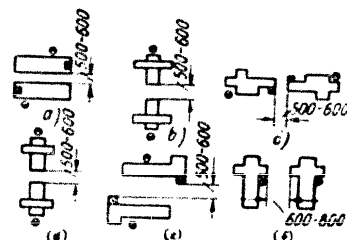


Fig.53 - Clearance between machine tools at Placement Back to Back

- a - For lathes; b - For universal-milling and gear-cutting machines;
- c - For transverse planing machines;
- d - For grinding machines; e - For turret and automatic machines at chucking work; f - For longitudinal-planing; longitudinal-milling, boring, flat-grinding machines of longitudinal type

between the boundary line of the reserved space on the front side of the machine tool and the column 700 mm; for placement of the tool machine with the back side

toward a column, between the column and the boundary line of the reserved space of the machine tool 500 mm (Figs.52a and b);

b) For lathes - between column and front line of reserved space of machine tool, 600 mm; between column and back side of machine tool, 500 mm (Fig.52c);

c) For milling and grinding machines - between table and column 700 mm; between column and lateral side of machine housing 500 mm (Fig.52d).

5. For placement of machine tools back to back (Fig.53) the clearance between machines may be taken at:

500-600 mm for automatic lathes and turret machines for chucking work, universal milling, gear-cutting, transverse-planing and grinding machines (Figs.53a-e);

600-800 mm for longitudinal-planing, longitudinal-milling, boring, flat-grinding machines of longitudinal type (Fig.53f);

400-500 mm for vertical and horizontal milling machines;

300-400 mm for vertical drilling machines;

500-600 mm for radial drilling machines;

600-900 mm for vertical lathes;

600-700 mm for semiautomatic horizontal lathes;

500-600 mm for semiautomatic vertical multispindle lathes;

900 mm for vertical broaching machines;

500-600 mm for horizontal broaching machines at rectilinear placement;

700-800 mm for placement at an angle (here, and furthermore, the smaller dimension relates to small machines and the greater dimension to large machines).

For the placement of automatic and turret machines (for chucking work), for convenience of their supervision, the machines must be displaced relative to each other in the transverse direction.

6. The clearance between machine tools along the line of their placement (Fig.54) should be taken at:

500-700 mm for lathes, multicutter lathes, gear-cutting, transverse-planing,

round-grinding, turret machines for chucking work - for rectilinear placement and bar work - for placement at an angle of 15° or staggered (Figs. 54a, b, c, d, e, f, g);

400-500 mm for vertical and horizontal universal-milling machines (Fig. 54b);

500 mm for vertical-grinding and radial-grinding machines;

600-700 mm for semiautomatic horizontal lathes;

900 mm for semiautomatic multispindle vertical lathes;

700-900 mm for vertical lathes;

600-800 mm for vertical broaching machines;

700-800 mm for longitudinal-planing, longitudinal-milling, boring, broaching machines (at rectilinear placement or at an angle; for placement at an angle the clearance is reckoned from the end points of the machine tools), flat-grinding machines of the longitudinal type (Figs. 54h, i).

On the machine line of assembly production in the presence of transport means connecting and serving the working places (slideways, ramps, rollways, etc), the clearance between the machine tools in the longitudinal direction is determined by the dimensions of these means.

7. The clearance between two tool machines tended collaboratively by two workers in the absence of a moving transport trolley is 1300-1500 mm (Fig. 55c); for tending two machine tools by one worker, 800-900 mm (Fig. 55b); for tending three machine tools by one worker, 500-600 mm (Fig. 55a).

8. The clearance of the payout plate or verification plate from the nearest machine tool or workbench is 1000 mm, from the wall 700 mm (Fig. 56).

9. The dimensions of the main passageways between machine tools intended for the transport of materials and products and the movement of persons are determined according to the outside dimensions of the transport means (manual, electric, motor trolleys, motortrucks, tractors, rollways, conveyors, etc).

The reserved space for the trolley must be taken according to the size of the

largest transported element, taking into account the ends of the element projecting beyond the limits of the platform. If the dimensions of the element are not greater

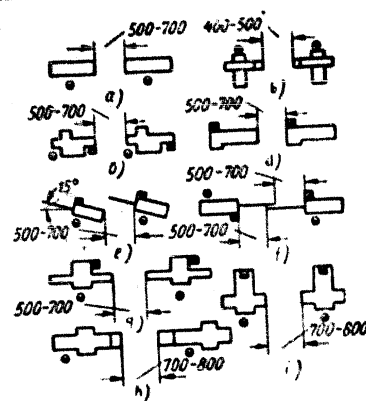


Fig. 54 - Clearance between Machine Tools Along their Line of Placement:

- a - For lathes; b - For milling machines;
- c - For transverse planing machines;
- d - For automatic and turret machines for chucking work; e - For automatic and turret machines for rod work and placement at an angle; f - For automatic and turret machines at staggered placement;
- g - For round-grinding machines; h - For longitudinal-planing, longitudinal-milling, boring and broaching machines;
- i - For flat-grinding machines of longitudinal type

into account the interval between two loaded trolleys for passing each other), the

than the outside dimensions of the trolley, it is taken according to the width necessary for direct passage of the latter.

Minimal clearance between machine tools according to the width of main passageway movement in one direction of electric and motor trolleys with loading capacity of 1.0-2.0 tons (at width of straight passageway 1200 mm):

a) 2000 mm with placement of machine tools with back side toward the passageway (Fig. 57b)

b) 2400 mm for placement of machine tools of the one row with the front side and of the other row with the back side toward the passageway (Fig. 57b);

c) 2800 mm for placement of machine tools with the front side toward the passageway (Fig. 57c).

For the possibility of two-way movement of electric and motor trolleys at the same minimal clearance between machine tools according to the width of the main passageway for the same methods of placement of the machine tools (taking

dimensions are 3600, 4000, 4400 mm respectively (Fig.58).

At employment of electric and motor trolleys of high loading capacity, and also of transport means for other types and sizes (automobiles, platforms, wagons, etc),

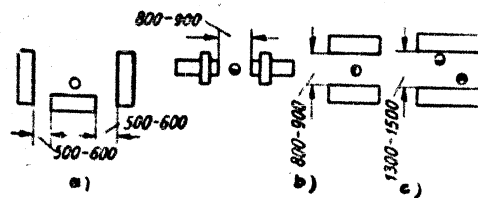


Fig.55 - Clearance between Two and Three Machine Tools Tended by Two or One Worker

the clearance between machine tools according to the width of the main passageway is taken in accordance with the outside dimensions of the employed transport means.

Accordingly, the size of the main passageway depends on the size and weight of the elements and the employed transport means: the greater the size and weight of the elements, the greater will be the width of the main passageway.

The width of the passageway for motortrucks is taken at 3500 mm in the short (transverse) direction and at 4000 mm in the long (longitudinal) direction.

The clearance between two rows of machine tools for placement of a rollway (or conveyor) between them is taken for the width of the rollway or conveyor B plus 1400 mm (Fig.59); at two rollways (or conveyors) this clearance equals twice the width of the rollway 2B plus 1500 mm (Fig.60).

The clearance between two rows of machine tools for placement of a suspended conveyor between them is taken equal to the greatest width of the transported elements plus 1500 mm; at two parallel suspended conveyors it is taken equal to twice the width of the transported element plus 1700 mm.

Secondary passageways are formed by the intervals between the machine tools, and can serve for the passage of persons to the machine tools.

Machine tools are placed in the aisles in two, three, and four rows, depending on the size of the machine tools and the width of the aisles. Large machines are

placed in the aisles in two, medium-sized ones in two-three, small ones in three-four rows.

For the placement of the machine tools in two rows a passageway for the transport is left in the middle along the aisle (Fig.61); for three rows of machine tools two longitudinal passageways may be provided for the transport (Fig.62) or one (Fig.63). In the latter case, the longitudinal passageway is formed between the

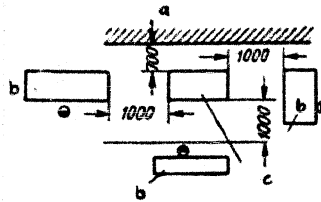


Fig.56 - Clearance of Layout or
Checking Plate from Wall, Machine
Tools and Working Places
a) Wall; b) Machine Tool; c) Layout
Plate

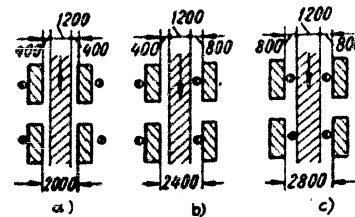


Fig.57 - Clearance between Machine
Tools for Movement of Electric Trolleys
in One Direction

single row and the double row of machine tools; for access to the machine tools of the double row lying at the columns, transverse passageways are left between the machine tools.

For placement of machine tools in four rows along the aisle two passageways are provided; along the columns the machine tools are placed in one row; a double row (machine tools back to back) is placed in the middle (Fig.64).

The machine tools may be placed along the aisle, across it (Fig.65) or at an angle (Fig.66 and 67).

The most convenient and a frequently adopted placement of the majority of machine tools is along the aisles. Transverse placement is adopted when it gives the possibility of attaining a better utilization of the floor space, and when

longitudinal placement gives an excessive amount of unnecessary passageway, and a large number of rows of machine tools is not called for. At this placement access to the machine tools is given by transverse passageways, which serve for delivery

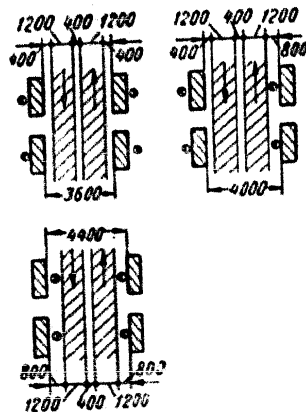


Fig. 58 - Clearance between Machine Tools for Two-Way Movement of Electric Trolleys

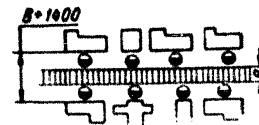


Fig. 59 - Clearance between Two Rows of Machine Tools for Placement between Them and Rollway or Conveyor

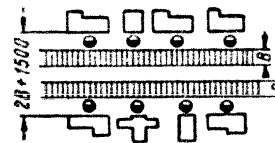


Fig. 60 - Clearance between Two Rows of Machine Tools for Placement between Them of Two Rollways (Conveyors)

of the elements by truck (electric, motor, manual) to the working places.

Placement of machine tools at an angle is adopted for turret and automatic machines at rod work, for broaching, drilling, longitudinal-planing, longitudinal-milling and longitudinal-grinding machines, and assures a better utilization of the floor space.

Turret and automatic machines for rod work are placed at an angle of 15-20° or somewhat greater depending on the width and length of floor space available for their placement; for this they are placed with the loading side toward the passageway. For staggered placement of these machine tools, the possibility of access to them from two sides must be assured (Fig. 66).

With all forms of placement of machine tools the working places should be provided with side passageways, which facilitate servicing of the working place (changing tools, supplying blanks, receiving elements, instruments, etc).

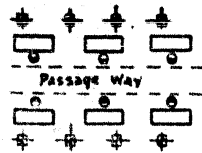


Fig. 61 - Placement of Machine Tools in Aisle in Two Rows with One Longitudinal Passageway

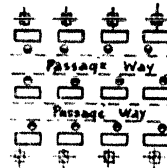


Fig. 62 - Placement of Machine Tools in Aisle in Three Rows with Two Longitudinal Passageways

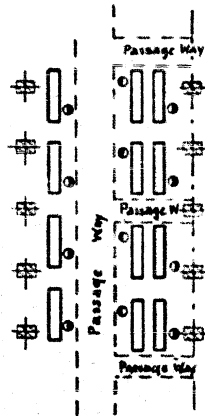


Fig. 63 - Placement of Machine Tools in Aisle in Three Rows with One Longitudinal Passageway

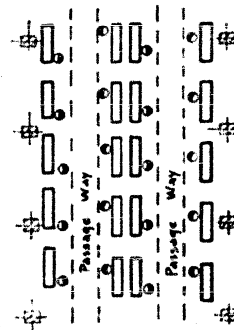


Fig. 64 - Placement of Machine Tools in Aisle in Four Rows with Two Longitudinal Passageways

In the flow line the machine tools are placed parallel (Fig. 69a) or perpendicular (Fig. 69b) to the tollway (or conveyor); the machine tools may be installed in the line of the rollway (Fig. 69c).

In the flow line there may be one (Fig. 70a) or two (Fig. 70b) rows of machine

tools, when the element goes from the one to the other row of machines. The flow lines may be straight with two parallel streams of elements (Fig.70c).

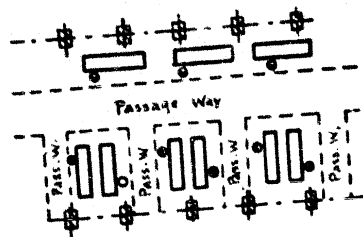


Fig.65 - Longitudinal and Transverse Placement of Machine Tools in Aisle

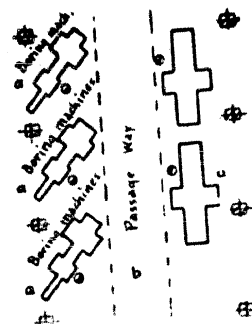


Fig.66 - Placement of Boring Machines at an Angle and Along the Aisle
a) Boring machines; b) Passageway, c) Longitudinal Planing machines

At fabrication of elements in a large number of operations the length of the assembly line obtained is considerable; in this case the assembly line is given a zigzag form, for equalizing its length with the assembly line of other elements, and so that the outflow of its finished elements will be in the direction common to all of the assembly lines (Fig.71)

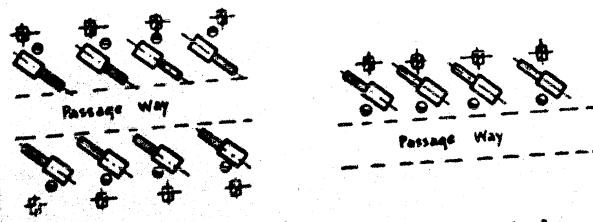


Fig.67 - Placement of Turret Machines at an Angle

For multimachine work, the placement of the machine tools to be operated simultaneously must be assured:

a) Location of the control organs for all of the tended machine tools most convenient for the worker;

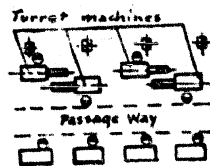


Fig.68 - Staggered Placement of Turret Machines

b) Minimal expenditure of time for changing from working at one machine to the other.

An example of a plan for six machine tools to be operated simultaneously by one worker is shown in Fig.72.

For multimachine work, when the machine tools are placed on both sides of a rollway, a break in the rollway for shortening the path of the worker between

machine tools should be made (Fig.73).

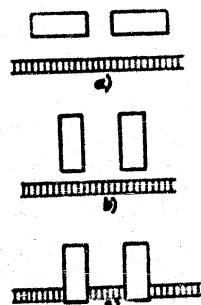


Fig.69 - Placement of Machine Tools:
 a)- Parallel with rollway; b)- Perpendicular to rollway; c)- Installed in line of rollway

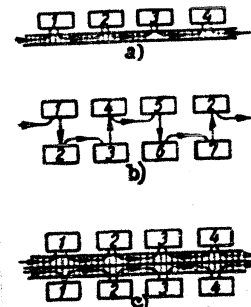


Fig.70 - Placement of Machine Tools in Assembly Line:
 a)- In one row; b)- In two rows; c)- In two rows with parallel streams of elements



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For ensuring the shortest path of movement of the elements and the most convenient placement of the machine tools for simultaneous operation by one worker, some

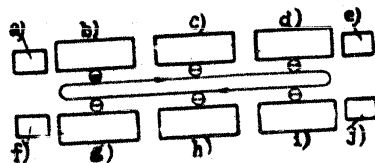


Fig. 72 - Arrangement of Six Machine Tools to be Used Simultaneously by a Single Operator

- a) Blanks; b) Finished parts; c) Operation 1; d) Operation 2; e) Operation 3;
f) Finished parts; g) Operation 1;
h) Operation 2; i) Operation 3; j) Blanks

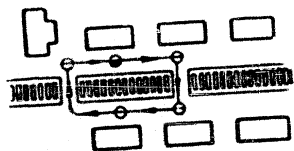


Fig. 73 - Arrangement of Machine Tools on Building Sides of a Roller Conveyor for Simultaneous Serving

of the machine tools are given in the assembly line in different positions - not rectilinear and not perpendicular to the axis of the aisle.

An example of such a placement of the machine tool is presented in Fig. 74.

In Fig. 75, the planned equipment of an assembly line for the fabrication of pistons with employment of a belt conveyor is shown.

A diagram of the planned equipment of an assembly line for the fabrication of

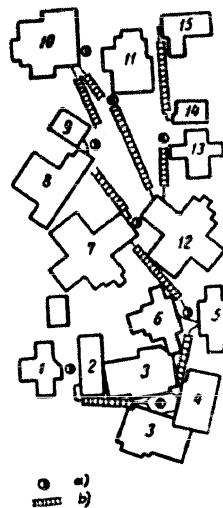


Fig. 74 - Arrangement of Machine Tools in Production Line Shortening the Travel of the Parts of the Operation

- a) Operator; b) Roller Conveyor

pendent conveyors and rollways is represented in Fig.76 (Bibl.8).

Determination of the Floor Space of the Shop

The detailed planning of the production (machine) floor space is determined on the basis of the planning by formulation of the plan of the location for all of the

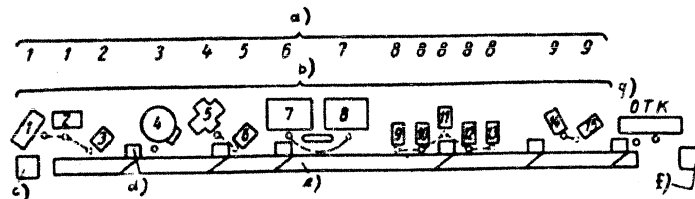


Fig.75 - Diagram of Planning Production Line for Machining Piston,

Using a Belt Conveyor. Operations:

- 1 - Boring Installation; Strip; 2 - Countersinking Openings; 3 - Turning;
- 4 - Milling Slits; 5 - Drilling Pin openings; 6 - Rough grinding;
- 7 - Finish grinding; 8 - Final boring of openings;
- 9 - Machine Tool No.

a) Operation No.; b) Machine tool No.; c) Bin for blanks; d) Receiving table; e) Belt conveyor; f) Bin for finished parts; g) Inspection

equipment, working places, conveyors and other arrangements, storage places for blanks and elements, passageways, corridors, etc.

On the fundamental plan the given width, length and number of aisles are indicated.

The width of the aisles, as can be seen from the plan, depends mainly on the outside dimensions of the employed equipment and transport means.

Enumerated below are some of the most frequently occurring widths of the aisles for mechanical shops, (i.e., clearances between axes of columns in the traverse direction of the aisles) depending on the kind of machine building:

12 m for light machine building;
 12, 15, and 18 m for medium machine building;
 15, 18, 21, 24, and 27 m for heavy machine building;
 up to 36 m for very-heavy machine building.

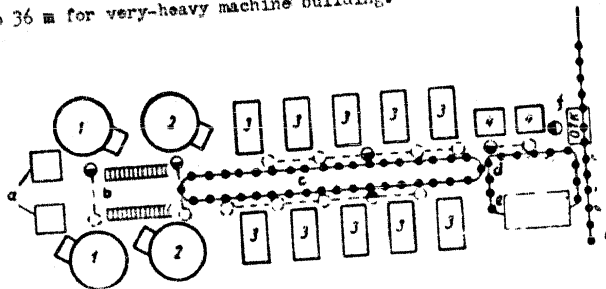


Fig.76 - Scheme of Planned Equipment of Assembly Line for Fabrication of Gears

1, 2 - Lathe treatment; 3 - Milling teeth; 4 - Gear-shaping machine
 a) Blanks; b) Rollways; c) Conveyor No.1; d) Conveyor No.2;
 e) Washing machine; f) Transport away; g) Conveyor to heat-treating shop

The same width for all aisles of the same mechanical shop is adopted. Sometimes one, two or more of the aisles are made wider than the rest for enabling the placement on them of larger machine tools than in the other aisles. It must be noted, however, that the employment of aisles of different widths in one and the same building increases the cost of construction; therefore, in the absence of extreme necessity and sufficient reason, the aisles should not be made of different widths in the same building.

The center-to-center clearance between columns in the longitudinal direction, called the pitch of the columns, is most frequently taken at 6 m, sometimes 12 m, depending on the kind of material employed for the building, its construction and loading.

The center-to-center clearances between columns in the longitudinal and transverse directions form the network of columns. In mechanical shops the most frequently employed networks of columns are 12×6 , 15×6 , 18×6 m; in heavy machine buildings the networks are larger: 21×6 , 24×6 , 27×6 , 30×6 m; in automobile and tractor building column networks of 12×6 , more frequently 18×6 , and also 12×12 and 8×12 m - in the absence of bridge cranes are employed.

The length of the aisle (along its axis) is determined by the sum of the dimensions of the consecutive production and auxiliary departments, passageways and other components of the shop. The length of the aisle must be a multiple of the column pitch and must be the same for all of the aisles (with some exceptions).

By establishment of the necessary width of the aisles, their number and length, the required floor space of the production (machine) departments of the shop is determined.

The height of the aisles of the mechanical shops in the presence of bridge cranes must be at least 6 m (from the floor to the crane railhead), or, in the presence of telfers or boom-cranes, at least 5 m.

Supplementary to what has been said about the determination of the dimensions of the building, i.e., the width, length and height of the aisles, also in regard to the column networks to be adopted, see Chapter XVIII.

The index characterizing the utilization of the production floor space of the mechanical shop is the specific area, i.e., the average area per machine tool. It is obtained by dividing the total area occupied by the machine tools including the passageway by the number of machine tools placed on it.

On the basis of this index, the satisfactoriness of the utilization of the production floor space of the shop is judged. The larger the size of the elements to be treated, as well as that of the equipment, the greater will be the magnitude of this index.

The average magnitude of this index for small machine tools is 10-12, for

medium-sized ones 15-25, for large ones 30-45, for the largest and unique machine tools of heavy-machine building 50-150 m² per machine tool.

The specific production areas of mechanical shops of various forms of machine building are presented in Table 14.

For enlargement planning, for the planning of buildings, and also in all cases when a plan is not formulated, the size of the production area of the mechanical shops is determined for the given form of machine building according to the specific area taken from approved projects or other sources.

Table 14
Specific Production Areas (i.e., Areas per Machine Tool) for Mechanical Shops
of Various Forms of Machine Building

Form of Machine Building	Specific Area in m ²
Motortrucks 3.5 m:	
Engine shop	12-14
Chassis and gearbox shop	10-12
Transmission shop	12-14
General	12-13
Caterpillar Tractors:	
Engine, chassis, transmission shops	12-14
Cylindrical and Roller Bearings:	
Automatic lathe shop	13-15
Bush shop	12
Grinding shop	11-13
General	14
Agricultural Portable Engines:	
Fittings shop	13-15
Steam engine-elements and driving-mechanism shop	22-24
High-speed Diesels of 5-15 hp	20-25
Crane of load-lifting capacity 5-15 tons	18-20
Rolling mill equipment (medium sized)	40-45
Locomotives of 30 type	40-45

Some examples of plans of equipment of mechanical shops are presented in Chapter IX.

22. Auxiliary Departments of Mechanical Shops

As already stated, auxiliary departments and storage places enter into the composition of mechanical shops, of which the following may be mentioned:

- 1) Readying department;
- 2) Sharpening department;
- 3) Reconditioning department (reconditioning base of mechanical shops);
- 4) Workshop for reconditioning of accessories;
- 5) Power-engineering staff;
- 6) Department for preparation and distribution of cooling liquids;
- 7) Department for salvaging cuttings;
- 8) Shop storages for materials and blanks;
- 9) Intermediate and emergency storage of elements;
- 10) Interoperations Storage;
- 11) Tool-distributing storage (or stockrooms - IIRK);
- 12) Storage of accessories;
- 13) Storage of abrasives;
- 14) Storage of oil;
- 15) Storage of auxiliary materials;
- 16) Inspection department.

Depending on the scale of production and the size of the shop the composition of the departments may be different - several departments and storerooms may be combined, in some cases several departments may be common to several shops. Thus, for example, for small and medium-sized shops the following are combined: the mechanical- and power-engineering departments, the intermediate and interoperations storeroom of abrasives and the storeroom of auxiliary materials.

For the planning of the shops, some of the enumerated departments and store-

rooms are formulated in detail on the basis of calculations, some (and sometimes) all are taken by analogy with going enterprises.

Let us examine the methods of calculating the numbers of required equipment and the areas of some of the largest of the auxiliary departments and storage places.

A. Readying Department

The readying department serves for slitting, cutting off, centering, straightening and descaling rod material (round, square, etc).

The readying department may be a part of or combined with the shop storeroom of materials and blanks, and is often its housekeeper but is sometimes an independent department. The readying department for medium and small mechanical shops is usually located in the storeroom. With large productions, it is a department of shop in which the readying of the operations for all of the shops of the works is carried out. In this case, the readying shop may either be located in the same building as the mechanical shops or separately in another building located more or less centrally to the shops, in which the blanks are prepared. Because of its many conveniences and advantages it is desirable to locate the readying shop in a place in the center of the whole works.

The rod material, of length 5-6 m, is cut up into pieces of certain lengths depending on the dimensions of the elements for which it is readied. The rod material is usually cut up into pieces of length 2-3 m; here, also, small pieces of round or square metal of larger section and in the lengths corresponding to the elements to be made from them are cut off. The cut pieces of rod material are centered and straightened. For doing this work, cutting-off machines, disk saws for round material of larger diameter, power shears, centering machines, and straighteners are provided in the readying department.

The determination of the necessary number of equipment for the readying department

ment usually occurs together with the formulation of the technological process of the readying operations (with preparation of a chart of the treatments and normalization of the times).

For small readying departments, the number of machine tools is determined by analogy with other workshops. Since the loading of the readying machine tools in such cases is small, it is usually sufficient to provide shearing and disk saws, cutting-off, centering, descaling and straightening machines or straightening presses.

For the formulation of the plan for the location of the equipment of the readying department, it must be borne in mind that for working on the machine tools carrying out the readying operations, long material is handled, and that free space must be left around the machine tools for placing the material and the blanks.

As a result of the plan for all the necessary equipment, the area of the readying department is determined. The specific area, i.e., the area per machine tool (together with passageways) is usually 25-30 m².

B. Sharpening Department

The endeavor to attain optimal results for the use of tools with respect to their length of service, and also full utilization of their cutting capabilities, depending principally on proper care and handling, leads to the necessity of centering all of the tool housekeeping in general and of the sharpening in particular.

With the modern organization of metal-frabiracint enterprises, the sharpening of the tools is centralized in a special separate sharpening workshop.

For servicing large and medium mechanical shops, the sharpening department is located in the shop itself; in shops with up to 200 machine tools, one sharpening department is organized. At the small mechanical shops, the sharpening department is located in the shop itself, while the tool shop is located in another building; with small mechanical shops and location of the tool shop in the same building as the mechanical shop, the sharpening department is located in the tool shop.

0 With centralized sharpening, the replacement of tools at the working places
2 may occur in two forms: 1) replacement of tools as required; 2) regular replacement
4 of tools.

6 In the first case, tools are replaced at the request of the machinist, who,
8 without leaving his working place and without interrupting his work, signals the
10 supplier to replace the dull with a sharpened tool. The machinist replaces the dull
12 tool with the sharpened tool taken from his supply. The tool received from the
14 supplier is kept in his supply for the next replacement.

16 In the second case, the tools are replaced at regular intervals of time corres-
18 ponding to the durability of the given tool, regardless of its condition. The
20 supplier serving the given section of the shop, periodically brings sharpened tools
22 to the working place and receives the dull tools from the machinist.

24 With the regular replacement of tools, excessive wear or damage is not observed,
26 as is the case with replacement at the request of the worker; consequently, regular
28 replacement of tools is more rational and better.

30 With the centralized method, the tools are sharpened in a special shop by
32 special workers.

34 Such a centralized sharpening of tools has the following advantages:

- 36 1) The tools are sharpened more correctly, because the sharpening occurs ac-
38 cording to drawings on special equipment and under special supervision;
- 40 2) Thanks to the specialization of the work for sharpening tools of a parti-
42 cular form, the tools are sharpened more rapidly;
- 44 3) The tool is ground down less at each sharpening, thereby increasing its
46 length of service;
- 48 4) Thanks to the proper geometry of the cutting part of the tool obtained at
50 the sharpening, the productivity of the tool is increased;
- 52 5) At regular replacement of the tool, it is not worn down to the extreme
54 limit, which also increases its length of service;
- 56

0 6) The principal machine equipment of the shop does not stand idle while tools
2 are being sharpened, thanks to which it is considerably better utilized.

4 As a result of all of the foregoing facts, the productivity of the equipment
6 and workers of the shop served by centralized grinding is considerably increased.

8 For maximally increasing the productivity and improving the quality of the
10 treated surface, the tool is lapped in a separated operation after its sharpening.

12 By lapping, a correct contour of the sharp edge is obtained, marks and rough-
14 nesses are eliminated, and the cutting edge is pointed.

16 Particularly important is the lapping of tools made of hard alloys. Because
18 these alloys possess great hardness and brittleness, the cutting edge of the tool
20 as delivered is sometimes nicked. Lapping eliminates the nicks.

22 Lapping is carried out on a special machine tool. Two end machines, i.e.,
24 having a disk on both sides, are very convenient.

26 The number of necessary sharpening machines is determined by the number of
28 tools to be sharpened per year, the number of sharpenings until complete utiliza-
30 tion of the tool, and the time required for the grinding. The calculation is as
32 follows.

34 The number of sharpenings of the tool until complete utilization of its work-
36 ing part, is determined by dividing the length of the working part of the tool (in
38 millimeters) by the value of the wear-off of the working part per sharpening (in
40 millimeters).

42 The number of sharpenings of the tool until its complete utilization is multi-
44 plied by the number of tools of the given type to be sharpened per year, which gives
46 the total number of sharpenings for this tool. Furthermore, the time necessary for
48 one sharpening in minutes, determining the norm, is multiplied by the total number
50 of sharpenings for all of the tools of a given type size, as a result of which the
52 total time required for the sharpening of all of the tools of a given type is ob-
54 tained (in minutes, which is then converted to hours). The latter is divided into
56

0 the actual yearly time fund of the sharpening machines and the number of shifts (as
1 described above for the calculation of the number of machine tools of the mechanical
2 shops), and in this way the number of sharpening machines is determined (coeffic-
3 ent, taking into account the idleness of the sharpening machines for general recon-
4 ditioning, $k = 0.97$). If a fractional number is obtained it is rounded to a whole
5 number (given number of machine tools).

6 By dividing the calculated by the given number of machine tools, the coeffic-
7 ient of loading of the machine tools is determined.

8 This calculation is conveniently carried out in the form of a table (Form 11).

9 The average number of sharpening machines necessary is 4-6% of the number of
10 machine tools served by the grinding machines (for large shops 4%, medium sized 5%,
11 small 6%).

12 The number of sharpening machines is determined not by detailed calculation,
13 but in a percentage of the number of machines served by the sharpening machines.

14 For carrying out such a calculation, there is selected from the total number
15 of machine tools of the mechanical shops for the sharpening of whose tools there
16 are required special sharpening machines. For serving these machine tools of the
17 mechanical shops, the number of special sharpening machines of each type is deter-
18 mined (according to Table 15).

19 After excluding from the total number of machine tools of the mechanical shops,
20 the machine tools for the sharpening of whose tools special sharpening machines
21 are required, on the remaining number of machine tools of the mechanical shops
22 according to the above-mentioned percentage the total number of general-purpose
23 sharpening machines is calculated. This number of general-purpose sharpening ma-
24 chines is distributed by types

25 It should be noted that special sharpening machines are provided in the sharp-
26 ening department only if they will be loaded at least 50%.

27 The number of lapping machines is calculated in the same way.

Form 11

Calculation of Numbers of Sharpening Machines

a	b	c	d	e	f	g	h	i	j	k	l

a) Serial No.; b) Name of tool; c) Required number of tools; d) Number of sharpenings until complete utilization of one tool; e) Total number of sharpenings for all of the tools; f) Sharpening time per tool in minutes; g) Total time required for sharpening all tools, in hours; h) Calculated number of machine tools; i) Given number of machine tools j) Coefficient of loading; k) Name of sharpening machine; l) Remarks

The number of lapping machines may also be determined in a percentage of the number of machine tools necessary for the sharpening of the tools to be lapped (it is given at 50% of the mentioned number of sharpening machines).

In the composition of the sharpening department there must be machine tools for sharpening; cutters of lathes, planing machines, automatic machines, turret machines; cutters made of hard alloys; drills, milling cutters (universal sharpening machines); milling heads; gear-cutting cutters of gear-planing machines; gear-shaper-cutter heads (universal-sharpening or grinding machines or universal sharpening machines with accessories); broachers; dies; taps; blades of circular segmented saws.

Table 15
 Examples of Percentual Ratios of Special Sharpening Machines of
 Given Types to Number of Machine Tools in Mechanical Shops
 Served by Them

Name of Sharpening Machine	% Sharpening Machines of Given Type to Number of Machine Tools Served by it
For worm-milling cutters	8
For milling heads	5
For gear-shaper cutters with straight teeth	3
For gear-shaper cutters with spiral teeth	7
For broachers	5
For special cutters of gear-planing machines	2
For disk heads of gear-cutting machines	25
For heads with gear-cutting machines for cutting gears with spiral teeth	15
For dies	One sharpening machine to department
For scourers*	5
For circulated segmented saws	One sharpening machine to works
* Sharpening of scourers usually occurs in tool shop.	

The area of the sharpening department for detailed circulation is determined on the basis of the plan of the machine tools; the productive area is 7-8 and the total area of this department 8-10 m² per machine tool.

Into the auxiliary area of the department enter the following: a) the area for keeping the drawings of the tools to be resharpened; b) the area for keeping the grindstones and accessories of the machine tools of the sharpening department.

The sharpening department should be located close to the tool storeroom.

The delivery of tools from the distributing to the sharpening department conveniently occurs at special windows. From the sharpening department the tools are delivered to the checking table at the distributing department.

Table 16
Examples of Percentual Ratios of General-Purpose Machine Tools by Types
in Sharpening Department

Name of Machine Tool	% of Total Number of Sharpening Machines
Universal Sharpening	40-50
Sharpening for cutters of high-speed steel	12-20
Sharpening for cutters of hard alloys	12-20
Sharpening drills	10-20
Universal grinding	6-10
Flat grinding	6-10
Pedestal grindstones	0.5-1

A grinding workshop located in a mechanical or other shop is separated by a glass partition. For removing the abrasive dust of the machine tools working "in the dry" an exhausting arrangement must be provided.

The sharpening department in mechanical shops of individual and series production is often located in the center of the sections of the shop served by it.

In the mechanical shops of flow production, the sharpening department is located outside the production stream, in an annex shop, where other auxiliary departments and rooms are also located.

The number of workers for sharpening is determined on the basis of the time norms for sharpening or according to the number of sharpening machines, taking

1.7-2 men per sharpening machine.

The younger service personnel is 2-3%, the engineer-technical 6-10% and the accounting office 4-5% of the total number of workers.

C. Reconditioning Department of Shop (Reconditioning Base)

As mentioned earlier, into the composition of the mechanical shop, a reconditioning shop enters (called the reconditioning base), present in the leading shop.

The reconditioning department takes care of the equipment, inspects and checks it, carries out regular, intermediate and unplanned repairs, and also sometimes general reconditioning of equipment on the spot (usually general reconditioning and production of spare parts occurs in a reconditioning-mechanical shop).

In small mechanical shops (less than 60 machine tools) the provision of a reconditioning department would be uneconomical; all forms of repair work for these shops are carried out in the reconditioning-mechanical shop.

In large mechanical shops (more than 600-700 machine tools) the reconditioning department is a department of the recondition-mechanical shops; they are calculated in the same way as reconditioning-mechanical shops.

The number of machine tools of the reconditioning department necessary for the mechanical treatment of reconditioned or new elements for the equipment is determined in percentage referred to the number of equipment present in the mechanical shop; it is taken between 2.5-5%, at which the smaller values relate to shops with larger number of equipment:

For shops with 600-300 machine tools	2.5-3%
For shops with 200-100 machine tools	3.5-4%
For shops with 80-60 machine tools	4.5-5%

The obtained total number of machine tools of the reconditioning department is distributed by types in approximately the following percentual ratios:

Screw-cutting lathes	45-50
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Drilling machines	20-25
Transverse planing machines	12-15
Universal milling machines	12-15
Round-grinding machines	7-10

For this, the total number of machine tools must make 100%.

The total area necessary for the placement of the machine tools and the execution of the mechanic-assembly work is determined on the basis of the plan. For enlargement planning, which usually includes such a department, the total of the reconditioning department is determined on the basis of the average sum of the areas per machine tool, which is taken at 23-38 m² (the smaller value relates to the shop with the larger number of machine tools).

Of the total area of the reconditioning department, approximately 40% belongs to the machine section, 25% to the mechanics section, and the remaining area to the auxiliary, store and service rooms.

The reconditioning department is located in an aisle or in an annex to the shop building, where all of the other auxiliary departments of the shop are concentrated.

D. Workshop for Reconditioning of Accessories

In mechanical shops of mass production and in large shops of series production, where at least one accessory is present on each of the production machine tools, an independent workshop for reconditioning of accessories is organized.

The number of machine tools for the workshop is taken at 3.5-1.5% of the machine tools of the mechanical shop. The greater percentage applies to shops with up to 100 production machine tools and the smaller one to larger shops.

The total area for the machine tools and for the mechanics work is determined on the basis of 10-12 m² per machine tool, including the auxiliary areas (for keeping the reconditioning accessories and the spare parts thereto and other areas).

E. Department for Preparation and Distribution of Lubricating-Cooling Liquids

The supplying of the metal-cutting machines for the mechanical shop with lubricating-cooling liquids (emulsion, soda solution, oil, sulphocutting oil) may be organized according to the following methods: 1) central circulation, 2) centralized by groups, c) decentralized.

With the first method the cooling liquid is supplied to the machine tools from the central supply over piping; the exhausted liquid from the machine tools returns by gravity flow through underground piping to the central supply.

This method is employed in shops having a large number of machine tools of the same type operating with a limited number of different compositions of cooling liquid.

With the second method, the cooling liquid is supplied to the machine tools over piping from the central supply to distributing valves which distribute the liquid by groups of machine tools or by individual machine tools. With this system the exhausted emulsion and aqueous solution run down the drain, while the exhausted oil is returned for regeneration. This system is employed in shops having a large number of machine tools of different types requiring cooling liquids of different compositions.

The third method of supply - decentralized - consists in supplying the cooling liquids to the machine tools in containers; the exhausted liquids are removed in the same way. This method is employed in shops with a small number of machine tools.

The central installation for the preparation and distribution of the lubricating cooling liquids to the machine tools is located in the building of the mechanical shop, in which a special room for this purpose is assigned. In this room for the preparation of emulsion and soda solution a mixer is placed, to which water, steam, and compressed air are brought; the steam is produced by heating water, and the compressed air by agitation of the solution in the mixer. Here, also, is kept

the oil necessary for lubricating the machine tools of the shop.

The room of the central installation is, for fire safety, located at the exterior wall of the shop building, and has direct access to the outside.

The yearly consumption of lubricating-cooling liquids is determined on the basis of the number of equipment of the shop and the norms of consumption per unit equipment. The norm consumption of cooling liquid and oil is given according to practical data established on the basis of generalized works experience.

F. Department for Salvaging Cuttings

As the result of the treatment of metals by cutting, considerable quantities of cuttings are formed. The quantity of cuttings can be determined as the difference between the rough and finished weights of the products on the yearly program or else approximately in agreement with the data presented in Chapter III, Section 17.

The cuttings occurring at the treatment on the metal-cutting machines may be dirtied with oil or free of oil emulsifier and dry. The cuttings must be collected in the shop separately according to the kinds of metal in metal boxes or bunkers. Particular attention is given to the collection of the cuttings of nonferrous metals. The cuttings, contaminated with oil, are collected in boxes with a double bottom, so that the oil running off them can also be collected and utilized.

It should be noted that the volumetric weight of the cuttings, particularly of steel shavings, is ten times less than the specific gravity of the metal, so that for the planning, provisions must be made for sufficient room for keeping the cuttings.

The cuttings from the machine tools are brought into collection boxes or bunkers located in the shop corridors with the help of trucks (electric, motor), electric trolleys on monorails, cranes and transporters. Belt, apron, scraper, and inertial conveyors may be employed. A pneumatic transporter may be adopted for removing small cuttings. For steel cuttings on lathes, it is advantageous to employ a cut-

tings breaker for breaking up the spiral cuttings.

The boxes or bunkers loaded with cuttings are taken to the salvaging department in electric or motor trucks, tractors or by means of conveyors; for this purpose, suspended chain conveyors with boxes are often employed.

The execution of the cuttings-salvaging process is formulated as follows: disintegration of spiral cutting, centrifuging of oil-contaminated cuttings, briquetting of considerable quantities of cuttings.

If the works has some relatively-large mechanical shops, the salvaging of the cuttings may be centralized in one department, to which there are brought the cuttings from all of the shops.

If the works has large mechanical shops, the salvaging of the cuttings occurs in a department provided for each of the shops.

Iron cuttings are directly briquetted or else transported away from the works.

Steel shavings not contaminated with oil are broken up and then briquetted, or else are charged into bunkers for transport away from the works.

Oily steel shavings are broken up and centrifuged, and then either briquetted or sent away from the works.

Oily fine steel cuttings go directly to centrifuging and then to briquetting.

The numbers of cuttings breakers and of centrifuges for separating the oil from the cuttings are determined on the basis of the quantities of cuttings occurring in the shops and the productivity of the equipment for their salvaging.

G. Shop Storages for Materials and Blanks

Shop storages for materials and blanks are provided for keeping the supplies of rod-form and other materials and of blanks (castings, forgings, stamping), and must be combined as much as possible with the readying department.

Such storages are provided with the mechanical shops (or departments) of series and individual production.

In the shops of mass-flow production, instead of such storages storage areas

are provided at the beginning of each assembly line (at the ends of the assembly lines there are areas for temporary storage of the finished elements), and only the transmission department is provided with storages for the rod material.

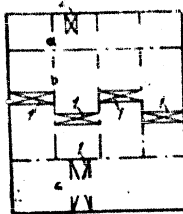


Fig. 77 - Location of Shop Storage of Materials and Blanks in Aisles of Mechanical Shop

1 - Bridge crane; 2 - Bracket crane

a) Storage of materials; b) Mechanical shop; c) Assembly shop

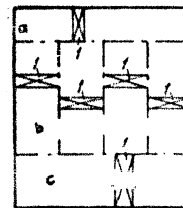


Fig. 78 - Location of Shop Storage of Materials and Blanks in Aisles Perpendicular to Aisles of Mechanical Shop

1 - Bridge crane

a) Storage of materials; b) Mechanical shop; c) Assembly shop

The supplies of materials and blanks in the shop storages must be small, and must only assure the regular supply of the shops with materials and blanks for assuring the operation of the machine tools. This requirement is based on two Considerations:

- 1) The shop must not have excessive supplies of materials in order not to regard the turnover of materials, i.e., not increase the turnover of necessary means;
- 2) Because the material storages are located in the production building, excessive supplies thereof would occupy valuable production areas, which, of course, is irrational.

Starting from the foregoing, the calculation of the necessary area of the storage should occur on the basis of the following supplies:

For series production: merchant materials and blanks, small and medium sized

for 5-10 days; large blanks for 2-3 days;

For large-series production: merchant materials and blanks, small and medium sized for 3-5 days; large blanks for 2-3 days;

For mass production: merchant materials, for transmission department for 2-3 days; small and medium-sized blanks on storage areas of assembly lines for 0.5-1.0 days; large blanks on storage areas of lines for 0.25-0.50 day.

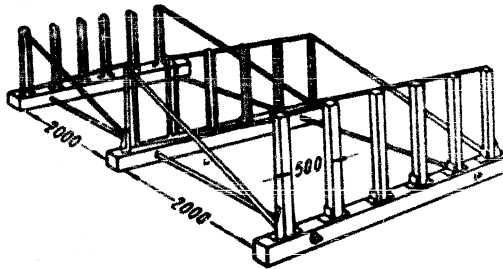


Fig.79 - Scaffold for Horizontal Storage of Red Materials

For obtaining the direct and shortest path of movement of the materials and blanks to the respective groups of machine tools, the storage is located at the front of the shop; for this, it may be located:

- a) In the front of the aisles of the shop perpendicular to the longitudinal axis of the line, i.e., transverse to the aisles of the building (Fig.77);
- b) In a separate aisle perpendicular to the mechanical-shop aisle (Fig.78);
- c) Under a trestle joined to the shop building, perpendicular to its aisle.

The two latter methods of location are adopted for storage of the blanks and materials of heavy-machine building shops.

In the first two methods of storage location, the materials and blanks are kept in the storages corresponding to the aisles in which they are treated; in these storages, they are sorted in each of the aisles according to type and size of machine involved.

The rod materials are stored in horizontal (columnar) scaffolds (Fig.79) in cellular or adjustable shelvings (Figs.80 and 81), or in vertical (pyramidal) shelvings (Fig.82).

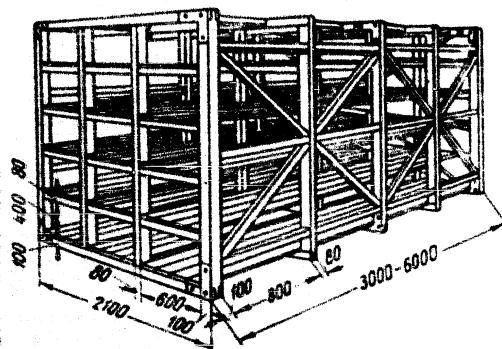


Fig.80 - Cellular Shelving for Storage of Rod Materials

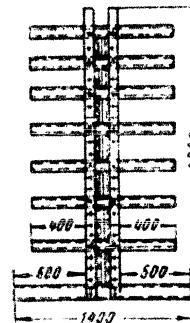


Fig.81 - Adjustable Shelving for Storage of Rod Materials

In the first case, the area occupied by the rods is larger, but with this method the transport of the rods is more convenient, particularly for their transport in bundles with the help of cranes; in the second case, less area is required for keeping the rods, but their handling is less convenient, particularly of long rods, and their transport with the help of the crane. For vertical storage long rods (5-6 m) are cut in half.

Large forgings and castings are stored on the floor in individual pieces or in piles; medium-sized forgings may be kept in piles on the floor, small ones in pigeonhole shelving (Fig.83). The shelving is made of wood, metal or mixed construction. The construction and dimensions of the shelving are determined according to the kind, form and dimensions of the blanks for whose storage they are intended. A very convenient shelving consists of individual sections. The size of

the pigeonholes is taken depending on the size of the blanks. The depth of the pigeonholes for keeping the blanks may be taken at 550-600 mm, the width at 700-750 mm, the height at 600-700 mm, the height of the whole shelving at up

to 2.5 m. Universal shelving is made with repetition of the dimensions in plan of 550 x 1100 mm or 600 x 1200 mm at a total height up to 2.5 m.

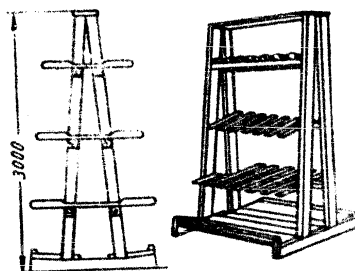


Fig.82 - Pyramidal Shelving for Vertical Storage of Rod Material

The shelves are placed along or across the storeroom (Fig.84). Longitudinally (relative to the storeroom) located shelves shut off access of the light through the windows in the face of building. For longitudinal location of shelves, some longitudinal corridors or

passageways are made, whose width must be sufficient for the passage of transport; this diminishes the utilization of the area of the storeroom. For transverse location of the shelves relative to the storeroom, one middle or lateral corridor along the storeroom is sufficient, so that with this arrangement of the shelves the area of the storeroom is best utilized.

The width of the passageways between shelves for the employment of hand trucks is taken at 0.7-1.0 m, for the employment of electric and motor trucks at 1.25-2.0 m and more, depending on the employed transport means.

The main passageways inside the storeroom must always be free for the passage of electric, motor and hand trucks; its width must be 2.5-3.0 m. For the necessity of the employment of automobile transport its width must be at least 4 m; if a railroad line enters the storeroom, the width of the passageway is determined according to the required clearance.

The total area of the storeroom is determined on the basis of the planned

shelves together with the area for keeping the supplies of the individual forms of materials and blanks for the above-mentioned periods, taking into account the passageways and corridors.

The size of the area for keeping the supplies of the various materials or

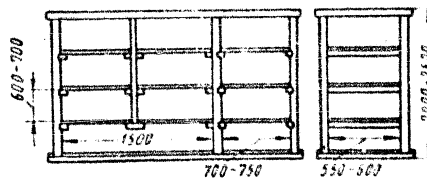


Fig.83 - Plain Shelving

blanks for the given periods is determined depending on the method of stowing and storing the materials.

The area for storing blanks in individual pieces may be determined according to

the overall dimensions of the blanks. Accordingly, provisions must be made on the plan for such blanks in the quantities necessary for the given periods; the supply of blanks must be small (for 2-3 days). It should be noted that large forgings and castings should not be kept in the shop storeroom; they must be brought to the working places directly from the storerooms of the readying shops where they are produced.

The area for the storage of the blanks on shelves may be determined by the location of the shelves necessary for the purpose. The dimensions of the pigeon-holes, their number, the number of tiers, the total height and length of the shelving must be selected in such a way that they are sufficient for the storage of the supplies of blanks for the given periods.

The area for the storage of blanks in piles on the floor, and of merchant materials piles or on shelving, for the given periods is determined according to the load/m² of floor area, which is taken on the basis of the load permitted by the construction of the floor, taking into account the convenience of storage of the materials and of putting them in and taking them out of stock. For the location of shop storerooms in one-story buildings the loading stress of the floor of the

storeroom is taken at:

For merchant materials, up to $2.0-2.5 \text{ tons/m}^2$;

For castings, forgings and stampings of small and medium size, up to $1.2-1.8 \text{ tons/m}^2$;

For large blanks, up to 2.5 tons/m^2 .

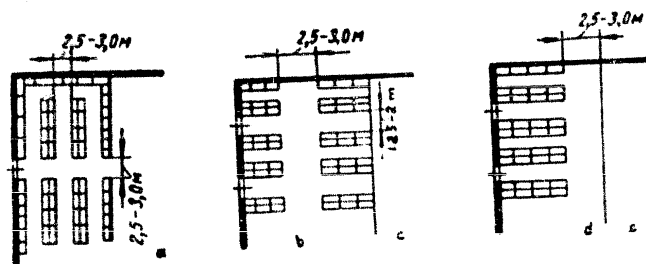


Fig.84 - Transverse and Longitudinal Location of Shelves in Shop

Storerooms

a) Mechanical shop; b) Main passageway; c) Mechanical shop; d) Main passageway; e) Mechanical shop

For the location of storerooms on the second story or higher the load stress of the floor must not go above 1 ton/m^2 ; there will usually be a sufficient permissible load of 0.75 ton/m^2 .

On the basis of the permissible load stress of the floor area and the number of days of storage of the supplies of materials, the necessary area F may be calculated according to the following formula

$$F = \frac{Qt}{Dq} \text{ m}^2. \quad (163)$$

where Q is the rough weight of the materials or blanks to be treated in the mechanical shop in a year in tons;

t is the number of days of storage of the supplies of materials;

D is the number of working days per year (307);

q is the permissible load of the floor area (load stress) in tons/m².

According to this formula the useful area of the individual places of sections of the storeroom can be determined for the storage of individual sorts of materials and particular forms and sizes of blanks.

The dimensions determined in this way for the areas of the storage of the individual forms of materials and blanks in shelving, on the floor, in piles of individual pieces, must be entered on the plan of the location of these places or sections, leaving between them passages and corridors, whose dimensions must be determined to correspond with the dimensions of the employed transport means. As stated above, the places of sections for the storage of the various blanks or materials must be located in the aisles of the shop in which the various materials or blanks will be treated.

As a result of such planning, the necessary total area of the storeroom is determined.

It is simpler to determine the area of the whole storeroom without dividing it into individual sections for the various sorts of materials and blanks. In this case, the calculation occurs according to the average-load stress of the floor area of the whole storeroom, taking this load stress at 1.5 tons/m². Employing for this case eq.(163), in which Q denotes the weight of all of the materials and blanks passing through the storeroom and undergoing treatment in the mechanical shop in a year, and taking into account the area for passageways and corridors, we get the total value of the storeroom F₀ according to the equation

$$F_0 = \frac{Q_{\text{dep}}}{Dq_{\text{cp}}h_n} M^2, \quad (164)$$

where Q₀ is the total rough weight of all of the materials and blanks undergoing treatment in the mechanical shop in a year in tons;

t_{sr} is the average number of days for which the supplies of materials and

blanks are kept;

q_{ar} is the average load stress of the area of the storeroom in tons/m²;

D is the number of working days in a year (307);

k_u is a coefficient of warehouse floor-space utilization.

k_u is a coefficient expressing the ratio of the useful area of the storeroom to its total area, taking into account the areas occupied by passageways, corridors, places for sorting of materials and blanks; its value may be taken at 0.5.

The area of the shop storeroom, according to a number of executed projects, is approximately 10-15% of the area of the machine department of the shop; the area of the shop storeroom together with the readying department is 15-20% of the machine area.

For transport of the materials and blanks inside the storeroom and from the storeroom to the machine tools, various transport means are employed.

For location of the storeroom across the aisles of the shop, bridge cranes are also used for bringing the materials and blanks from the storeroom to the machine tools, which serve the aisles of the mechanical shop, and can go into the storage places of each of the aisles (Fig.77). In this case, the transport of the load with the bridge crane within the limits of the whole storeroom is, of course, impossible. For this purpose, a suspended monorail line with telfer may be employed besides trucks (hand, electric, motor) located along the storeroom, bracket and velicopede cranes, running parallel with the face wall of the building.

In large shops, as already mentioned, the storeroom is located in a separate aisle perpendicular to the aisles of the mechanical shop (compare Fig.78). In this, the storeroom is provided with its own bridge crane, which serves the whole storage area. For bringing the load into the aisles of the mechanical shop the bridge crane of the shop must be able to pass below the bridge crane of the storeroom, so that the height of the storeroom aisle must be greater than the height of the shop aisles. When it is impossible to build the storeroom higher than the mechanical aisles, and

0 locate the bridge crane of the storeroom at the same level as the bridge crane of
the mechanical aisles, the transport of the loads from the storeroom under the
crane of the mechanical shop may occur with the help of trucks.

1. Intermediate and Interoperational Storage of Elements

After verification in the control department, the elements enter the inter-
mediate storage, located at the end of the aisles of the mechanical shop after the
control department on the path of movement of the elements from the mechanical to
the assembly shop.

The intermediate storage serves for accumulating and storing finish-treated
elements awaiting assembly, and for supplying finished elements to the assembly
shop. The intermediate storage assures uninterrupted and systematic assembly and
output of finished products.

For individual production, the supply of elements in the intermediate storage
is taken at twice the number of machines assembled at the same time, so that rather
large numbers of elements are accumulated in storage, particularly at a long process
of their production. For individual production, the assembly of the product begins
when all of the fundamental parts of the machine are present in finished form in
storage. If assembly begins in the absence of some of the necessary parts, incom-
pletely assembly machines may be left standing in the assembly shop occupying valu-
able floor space.

The necessity of having on hand all of the fundamental finished elements of the
machine before starting the assembly, requires a considerable area of the inter-
mediate storage; this is especially the case with individual production.

For series production in intermediate storage, the numbers of elements neces-
sary for the assembly of one series of machines must be ready. Therefore, at this
form of production, the number of elements held in storage awaiting assembly will
be smaller than for individual production, so that the area of the storage will
also be smaller.

Preliminary assembly of aggregates considerably decreases the supply of elements in storage, and therewith also the dimensions of the storage, but for keeping the aggregates, the provision of considerable storage places is necessary (around the place for the assembly of the machines).

The supply of elements in intermediate storage for small series and series production should be taken for not more than ten days demand (supplies of small elements may be taken for up to two weeks demand); for large-series production at 5-7 days demand, at which it must not be taken the same for all of the elements: for large elements for 2-3 days, for medium-sized ones for 3-5 days, for small ones for 2-3 days.

For mass-flow production, instead of an intermediate storage, storage areas for finished elements are provided at the ends of the assembly lines. The supply of elements for these areas usually equal the requirements of the assembly process for 0.5-1.0 day (24 hours).

The elements in intermediate storage are kept on plain shelves with pigeon-holes of the same types as those employed for the storage of blanks and materials (described above).

The width of the passageways between the shelves for the employment of hand trucks is taken at 0.7-1 m, and for the employment of electric or motor trucks at 1.25-2 m.

The width of the main corridors is taken at 2.5-3 m or more, depending on the employed transport means.

The total area of the intermediate storage is determined in the same way as that of the shop storage for materials and blanks, i.e., on the basis of the planned shelving and other means for the storage of the supplies of various forms of elements for the given periods, also taking into account the passageways and corridors, or, more simply, as is usually done, by one calculation of the storage area as a whole without dividing it into individual places for the storage of various details.

The load stress of the floor area of intermediate storage is taken smaller than that of material storage in shops, because most of the ready elements are kept on shelves or on special stands, tables and in containers. Ready elements must be stored carefully and accurately, so that the permissible load of the floor area should be taken at 0.5-1 ton/m².

The calculation occurs according to the same equation (164) as for intermediate storage, but in this case Q denotes the net weight of the ready elements passing through the storage in a year.

The area of the intermediate storage averages 10% of the machine area.

The storage of unfinished elements between operations occurs on areas especially provided for the purpose between the machine tools. On these areas the inspection of the elements is also carried out. Instead of such areas between machine tools, so-called interoperational storages are sometimes provided.

The area of the interoperational storages must be calculated not according to the "finished" weight, as is the case for finish-treated elements, but according to the average weight (approximately), which may be taken (with certain reservations) at 7-8% more than the finished weight, on the basis of the fact that the material rejected for the treatment averages 15%, and that half the rejection occurs at the first roughing operation. There also must be taken into account after how many operations, i.e., how many times, these unfinished elements come into storage; on the average for medium-sized machine building, 5-6 operations may be reckoned, after which the unfinished elements come into storage for awaiting treatment on the next machine tools.

It must be sought to limit as much as possible the duration of the stay of these elements in storage each time; for the calculation of the area of the storage for them the period should be taken for not more than 2-3 days.

The load stress of the floor area for the storage of unfinished elements may be taken in the same way as for finished elements. On this basis the total area

of the interoperational storage may be expressed by the following equation:

$$F_{o.m} = \frac{Q_{ch} k_o t}{D q k_u} \quad (165)$$

where $F_{o.m}$ is the total area of the interoperational storage in m^2 ;

Q_{ch} is the finished weight of the finished elements in tons;

k_o is a coefficient taking into account the weight of rejects of unfinished elements;

t is the number of days of stay of the element in storage each time;

i is the average number of operations after which the unfinished element arrives in storage;

D is the number of working days (307);

q is the load stress of the floor area in $tons/m^2$;

k_u is the coefficient of utilization of the storage area, taking into account the areas occupied by passages and corridors (≈ 0.5)

K. Tool-Distributing Storage (or Stockroom - IRK)

The tool-distributing storage serves for supplying the working places (machinists and mechanics) with tools and accessories.

In small and medium mechanical shops, one tool-distributing storeroom is provided for all forms of tools (cutting, auxiliary and measuring) and also for accessories. For large shops (with more than 200 machine tools) separate specialized storerooms for cutting, auxiliary and measuring tools, accessories and abrasives are sometimes provided.

For the same large shops, several general (not specialized) distributing storerooms may be provided, in such a way that each of them serves at least 100-125 machine tools.

For shops lying close together (particularly small ones) it is advisable to provide a common tool-distributing storeroom.

The tool-distributing storeroom is located in the shop alongside the sharpening department, and for individual and series production as nearly as possible in the central part of the shop, and for flow production on the side of the assembly line where the other auxiliary departments are located. For storing the tools and accessories, the storeroom is provided with shelves.

The area of the tool-distributing storeroom is determined by the number of working places served thereby. For calculating the area, an index serves expressing the area of the storage area in square meters assigned to one metal cutting machine of the served shop.

For keeping all forms of tools and accessories in one storeroom, the area of such a storeroom is determined by calculation on the basis of one machine tool of the served shop depending on the form of production: for small-series production 0.75 m^2 , for series production 0.65 m^2 , for large-series production 0.55 m^2 , for mass production 0.35 m^2 .

For serving the mechanics assembly parts the storage area must be taken at $0.15\text{--}0.25 \text{ m}^2$ per mechanic, at which the total number of mechanics for all of the shifts is taken, because the tools for the workers of all of the shifts must be kept in storage.

Furthermore, for the checking points and the mechanics department for minor repairs to tools and accessories, $15\text{--}20 \text{ m}^2$ must be taken (of which $15\text{--}20 \text{ m}^2$ for the mechanics department).

The area of the separate accessories storage is taken at $0.25\text{--}0.30 \text{ m}^2$ per machine tool of the served shop.

The area of the abrasives may be taken at $0.03\text{--}0.04 \text{ m}^2$ per machine tool of the mechanical shop.

The most convenient form for the distributing storeroom is a long rectangle, on whose long side the window for delivering the tools is placed; for this the shelves for keeping the tools are located perpendicular to the long side of the

rectangle.

L. Checking Department

The checking department, which is often common to the whole works, is located at the end of the mechanical shop on the path of movement of the elements to the assembly shop. Besides the checking department proper checking areas between machine tools are also provided in the mechanical shop, for which the elements are checked between machine operations, and (for treatment in lots) elements are kept until passed onto the next machine tools.

The planning of technical checking and of checking departments is described in Chapter VIII.

23. General Planning of the Mechanical Shop

All of the departments of the mechanical shop are located in the following order (in the direction of the general production stream):

- a) With series production - the shop storage of materials and blanks, either together with or next to the readying department, is located at the beginning of the shop (either transverse to the aisles of the shop or in a separate aisle perpendicular to the aisles of the shop); for flow production a storage area for the blanks is provided at the beginning of each assembly line;
- b) Along the storeroom or storage area, transverse to the aisles of the shop, a corridor of width at least 3 or 4 m or more is provided depending on the employed transport means;
- c) Next is located the machine department; for very long technological lines, transverse passageways of width at least 3 or 4 m are provided;
- d) At the end of the machine department, across all of the aisles, a transverse corridor of width at least 3 or 4 m is also provided, depending on the employed transport means;
- e) Next the checking department is located;

f) Parallel with the checking department, transverse to the aisles, the intermediate storeroom is located, and, together with it, the interoperational storeroom - if such is provided;

g) The sharpening department and the tool-distribution storeroom, as mentioned above, for flow production, are located outside of the flow, where all of the remaining auxiliary departments of the shop are located, in order not to impede the movement of the elements; for series production they are located in the shop as nearly as possible in the center of the served machine sections.

The storage places in the shop (storage of materials and blanks, intermediate storage, tool distribution) are separated from the machine department by a wire netting of height not greater than 2.0-2.5 m (for giving passage to cranes), the checking and sharpening departments by a glass partition.

Corresponding to the described sequence for location of the auxiliary departments of the shop and the plan of the equipment, the general components of the shop are formulated, as a result of which the number of aisles are determined, the width of the shop (in accordance with the given width of the aisles), the length of the shop (in accordance with the given pitch of the columns), and the total area of the shop (the determination of the width, length and height of the shop building is described in Chapter XVIII).

In the project of a given scheme, the general components of the departments of the shop are formulated on the basis of the areas calculated according to the specific areas and other technical-economic indices; in the technical project the general components of the shop are detailed, taking into account the necessary areas of the departments obtained on the basis of the plan of the equipment.

Examples of plans of the equipment and the components of mechanical and assembly shops are presented in Chapters II and XIX.

The shop plan is made in a scale of 1:100. For large shops (with more than 250 machine tools) it may be made in a scale of 1:200.

On the plan all of the machine tools and all of the other machinery in relation to the working places must be shown, i.e.:

- 1) Metal-cutting machines and other production equipment;
- 2) Stations of the workers at the machine tools during operation;
- 3) Working places without the equipment (on the floor or on special bases), with indication of the over-all space requirements;
- 4) Workbenches, worktables, stands;
- 5) Tool cabinets (tables);
- 6) Places at machine tools for treatment of elements and processing of blanks and materials;
- 7) Places for shelves and stands for elements and large tools;
- 8) Transport means in relation to the working places: ramps (chutes, troughs), slideways, rollways (compare Chapter IV);
- 9) Areas for checking and temporary storage of elements (compare Chapter VIII);
- 10) Places for workshops.

On the plan, the hoists and transport means of the shop must also be shown: bridge and boom cranes, conveyors and velocipede cranes, portal and semiportal cranes, rotary bridge cranes, telfers, tackles, rollways and conveyors, narrow- and wide-gauge tracks, elevators (on shop transport compare Chapter XV).

All of the corridors and passageways must also be shown on the plan in dot-and-dash lines, as well as tunnels or pits (in dashed lines) provided for production or transport purposes.

With regard to structural elements, the following must be shown on the plan:

- 1) The columns and axes and designation number of each column;
- 2) Outlines of bases of columns and foundations, shown in dashed lines;
- 3) Main exterior and interior walls;
- 4) Light interior walls and partitions, including glass and wire-netting partitions;

5) Windows, gates and doors, both exterior and interior;

6) Basements, underground rooms, mezzanines.

On the plan all of the necessary dimensions must also be given: width of aisles, pitch of columns, total width of shop, total length of aisles and of the whole shop, width of longitudinal and transverse passageways or corridors, width, length and area of each auxiliary department, clearances from machine tools to columns and between machine tools and working places, over-all space requirements of large machine tools.

All of the lines and dimensions on the plan must be drawn to scale.

All of the machine tools and equipment, as well as the appliances of the working places, the storing and checking areas, the lifts and transport means are shown on the plan, and denoted by serial numbers, and entered in the specifications, which are annexed to the plan. In the specifications the following must be indicated:

- 1) The number denoted on the plan;
- 2) The name of the equipment or appliance;
- 3) Their characterization: principal dimensions, loading capacity, area, etc;
- 4) The power of the electric motor of the respective equipment or appliance.

On the plan the number or name of the production departments of the shop must be noted, the production sections, the auxiliary departments, and also the name or number of the story (for multistory buildings).

If the shop is to be housed in a multistory building, on one sheet all of the stories, one above the other are shown, in such a way as to show all of the columns and all of the areas of all of the stories in their relation to each other.

Besides the plan, cross sections of the building in a scale of 1:50 or 1:100 must also be made; on the drawings of the cross sections of the building its height must be shown.

To the plan, copies from the general plan showing the location of the given shop in relation to the other shops must be annexed, and also the intraworks trans-

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- a) Suspended conveyor
- b) Chute and lift of suspended conveyor
- c) Telfer on monorail
- d) Pneumatic lift on monorail
- e) Electric tool on monorail
- f) Rotating crane at columns
- g) Boom crane with telfer
- h) Suspended boom crane with telfer
- i) Bridge crane
- j) Ordinary rollway
- k) Double rollway
- l) Plastic transporter
- m) Slideway, ramp
- n) Normal-gauge railroad track
- o) Steam with returning condensate
- p) Compressed air of 6 atm
- q) Compressed air of 3 atm
- r) Gas supply
- s) Water (supply)
- t) Water (run-off)
- u) Emulsion supply
- v) Oil supply
- w) Monorail line
- x) Mechanics workshop
- y) Checking table
- z) Storage place
- aa) Reserved place
- ab) Bunker
- ac) Shelving
- ad) Place for blasting
- ae) Roller path



Fig.85 - Tentative Denotation of Auxiliary Equipment and Piping

port line going to the given shop and its connection with the other shops, structures, storages.

All that has been said about the execution of the plan of the mechanical shop also applies to the plans of the other shops to be discussed later.

The tentative denotations of the auxiliary equipment and piping are presented in Fig.85.

The tentative denotations of the structural elements noted on the plans of the shops are present in Fig.181.

24. Principal Technico-Economic Indices of Mechanical Shops*

For determining the cost of construction and equipment of a projected shop and for ascertaining its technico-economic effectiveness, a number of technico-economic indices have been derived, of which some of the principal ones are as follows.

Absolute Indices Characterizing the Productive Capacity of the Shop

1. Yearly output of products in shop cost of production (in roubles) including spare parts (in roubles).
2. Yearly output of aggregates or machines.
3. Yearly output of products (in tons) including spare parts (in tons).
4. Number of working shifts.
5. Area of shop (in square meters): a) total; b) productive.
6. Number of productive equipment, including metal-cutting machines.
7. Number of workers, including: a) productive workers; b) auxiliary workers; c) younger service personnel; d) engineer-technical personnel; e) accounting-office personnel.
8. Fixed assets (in roubles), including:
 - a) Buildings and annexes; b) equipment, tools and accessories; c) productive

* For further details on the technico-economic indices compare Chapter XXI.

and housekeeping inventories.

9. Yearly budget of productive and all other wages.

10. Rated power of electric motors in kilowatts.

Relative Indices Characterizing the Technico-Economic Effectiveness of the Shop

11. Yearly output of products in roubles (in cost of production): a) per productive worker; b) per unit production equipment; c) per m^2 production area.

12. Yearly output of products in sets of elements and tons: a) per productive worker; b) per m^2 production area per shift; c) per unit production equipment.

13. Yearly output of products in roubles (in cost of production) per rouble fixed assets.

14. Yearly output of products in roubles (in cost of production) per rouble wages of productive workers.

15. Total area per unit production equipment in square meters.

16. Production area per unit production equipment in square meters.

17. Coefficient of loading of equipment (in time).

18. Coefficient of replacement.

19. Rate power per unit production equipment in kilowatts.

20. Labor expenditure for one set of elements (one machine) in machine hours.

21. Labor expenditure per tons output in machine hours.

22. Cost of production (shop) per ton production and set of elements per machine.

23. Structure of production cost (shop) in percent: a) materials; b) basic wages of productive workers; c) shop overhead.

24. Shop expenditures to basic wages of productive workers in percent.

CHAPTER IV
FUNDAMENTAL INFORMATION ON THE TECHNOLOGICAL PLANNING OF AUTOMATIC
FLOW LINES

25. Technological Processes, Equipment and Appliances

In mass production two different principles of execution of the technological process are employed.

The first principle is based on a differentiation of the technological process into elementary operations with assignment thereof the particular narrow-specialized machine tools, each of which carries out one particular operation.

The second principle is based on a concentration of the operations of the technological process on one automatic machine or on several such interruptedly connected with each other, carrying out automatically, simultaneously, or successively several operations, including treating and auxiliary actions.

In modern mass production it is sought to employ constantly more widely the second principle as giving the greatest technico-economic effectiveness. This principle is employed in automatic assembly lines more frequently than the first one. An automatic line consists of groups of interconnected automatic machines, transport means and apparatuses by means of which the operations of the technological process are carried out successively at fixed times with the participation of workers.

For the planning of an automatic line, the principal factors determining the character of the necessary equipment, tools and appliances are:

- 1) The number of elements to be treated in a year;
- 2) The most rational technological process of the treatment of the elements;
- 3) The form and size of the element and of its treated surface;
- 4) The material of which the element is made and its weight;
- 5) The tolerance on the treated surface of the element;

6. The quality of the treated element.

On the basis of the character of the element to be treated, the possible variants of the technological process are formulated, on whose basis the best sequence and most rational treatment is determined, the base surface, the methods of holding and fastening the element at the machining.

The form, size and weight of the element predetermine the character of the construction of the fastening and holding devices and of the transport means.

The treating procedure is established depending on the kind of material of the element, the strictness of the dimensions of the treated surface and the beat of the production line.

Automatic lines are employed for the treatment of cylindrical elements (rolls, bushes, rings), body elements (cylinder blocks, gear boxes), elements of complicated construction, elements made of sheet material.

Automatic lines may be of different forms depending on the character of the employed equipment:

Lines of universal machine tools consisting of the same type and of different types of machine tools;

Lines of special machine tools, consisting either solely of special machine tools or of both special and universal machine tools;

Lines of aggregated machine tools intended for the treatment of body cast elements (blocks and heads of cylinders for automobile and tractor engines, gear boxes, etc);

A combination of machine tools, constituting an automatic line essentially in the form of one machine tool, executing a series of successive operations of the treatment of the given element;

Lines of automatic production with complete cycle of production of elements, including aggregates for casting and heat treatments, devices for checking and sorting, means for painting and packaging (automatic works for production of pistons,

6 piston rings, piston pins).

Into the composition of automatic lines for mechanical treatment of elements the following equipment and apparatus usually enter:

- 1) Metal-cutting machines, automatic and aggregate, for executing technological operations;
- 2) Mechanisms for setting and fastening the element to be treated in the working position and the position required for the treatment;
- 3) Apparatus for transporting the element between machine tools and for returning the accessories to the place of loading;
- 4) Mechanisms for turning the element if required by the character of the treatment;
- 5) Apparatus for loading the elements and apparatus (magazines, bunkers) for accumulating the elements and feeding the next sections of the line;
- 6) Apparatus for removing the cuttings;
- 7) Devices and apparatus for checking and sorting the elements;
- 8) Apparatus for controlling.

For the selection of the types and of the numbers of the machine tools it must be sought to employ the smallest possible number of machine tools by employing multitool and multiposition machines, multicutter semiautomatic and automatic machines.

In the automatic line of aggregate machine tools, strong multispindle heads for simultaneous two- or three-sided treatment of one or two identical elements should be employed.

For distribution of the technological operations according to individual positions, it should be sought to concentrate in each position the largest possible number of actions of identical tools and to obtain approximately identical working duration of the individual heads of the tools; this is necessary for more complete utilization of the tools. Equalization of the working time of the tools is obtained

in various ways: by increasing the cutting speed of the limiting operation; dividing long operations in several parts, for example, drilling deep holes in parts successively in several positions (in the first position drilling a part of the length of the hole, in the second the next part, etc), two-sided (counter) drilling; employment of combination tools, etc.

The position in the automatic line through which the element being treated passes, has different meanings:

The working position serves for executing the treatment operation;

The checking position for checking the dimensions after treatment;

The idle position - for turning the element by a particular angle (90, 180°) for the necessity of treatment it on different sides;

The position assuring the necessary interval between the machine tools on the basis of their over-all space requirements and the necessity of having room for servicing, adjusting and repairing the machine tools;

The position for the removal of cuttings.

The element to be treated arrives in the working position, is fixed on the base surface, fastened, and treated; after treatment it goes to the next position.

The number of positions is established at the formulation of the technological process depending on the character of the treatment and the employed equipment, the number of simultaneously-employed tools, the necessity of checking the operations, and a number of other technological factors.

The cutting tool for the treatment of the element must possess a high durability and a great productivity. Replacement of tools must occur on interruptions in the operation of the line, at certain predetermined intervals of time, as much as possible, not less than every four hours, because frequent replacement of tools causes considerable idleness of the line.

The number of machine tools in an automatic line is determined according to the number of technological operations: the line may consist of several machine

tools (4-5) or of several tens of machine tools (30-40).

The preliminary treatment of the base surface of body elements (and also sometimes of others) usually occurs on machine tools not included in the automatic line.

The expenditures of time on the execution of the individual operations of the whole technological process must be as nearly as possible the same, which is necessary for assuring uninterrupted operation and observance of the working beat.

The working beat is established on the basis of the greatest machine time of one of the machine tools of the line, which limits the beat of the whole line. The shortening of the machine time of the limiting operation, and bringing it into agreement with the times for the other operations, is obtained by the selection of the cutting conditions and of cutting tools possessing high cutting characteristics and great durability.

The hourly productivity N of the whole line (i.e., the number of elements turned out per hour) is determined according to the equation

$$N = \frac{f_n}{t_1} = \frac{fk_n}{t_1}, \quad (166)$$

where f_n is the hourly actual fund of working time, expressed in minutes or seconds;

n is the number of elements treated simultaneously in the line;

t_1 is the operative (working) time of the limiting operation in seconds, into which the time for fastening, treating and unfastening the element enters, for putting in and taking out the power head, and also for loading and unloading the element;

f is the hourly nominal fund of working time, expressed in minutes (60 min) or seconds (3600 sec);

k_n is a coefficient taking into account the utilization of the total time for the actual work of the line.

The operative (working) time of the machine operations with distribution of the expenditure of time over the individual parts of the work (fastening, treating

and unfastening the element, putting in and taking out the power head) can be represented in the form of a cyclogram, in which the time of the limiting operation is graphically reflected.

In Fig.86, the cyclogram of the work of an automatic line consisting of 14

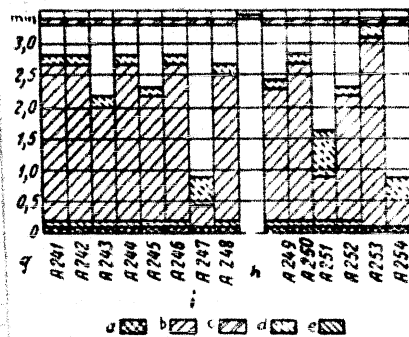


Fig.86 - Cyclogram of Work of Automatic Line:

a - Fastening element; b - Treating element; c - Unfastening element; d - Taking out power head; e - Putting in power head; f - Minutes; g) Machine tool; h - Revolutions of drum; i - Tentative denotation

transporter; while being treated in the working position the element is fixed and fastened in the accessory of the given aggregate.

If the configuration of the element is such that it is difficult to fix, it is placed in a movable accessory together with which it is transferred between machine tools; in the working position this accessory is fixed and fastened in a stationary accessory of the aggregate itself employed for the given operation.

machine tools for the treatment of heads and cylinders of tractor engines is presented by way of example (the technical characterization of this line is presented below). As can be seen from the cyclogram, the limiting operation is the operation on the vertical milling machine A253; the working beat of the line is 3.5 min.

For fixing and fastening the elements treated on automatic lines consisting of aggregated machine tools, special accessories are employed.

If the detail has a preliminary-treated surface which can serve as base and sliding plane, such an element is transferred (slid) without an accessory between machine tools on the

In an automatic line consisting of aggregated machine tools, the body detail being treated is the majority of cases based on a plane and two control openings, for example, cylinder blocks of automobile engines. For the transfer between machine tools, the block slides with its lower plane in the direction of the transporter.

The method of transport of the elements in the automatic line, depends on their construction and size, the character of the employed equipment and the methods of treatment.

In automatic lines consisting of aggregated machine tools, for transporting the elements, a stepped apron transporter making a reciprocating movement is usually employed.

For transporting the elements in lines consisting of universal and specialized machine tools, various transport means are employed: chain transporters (for elements of complicated form), multigrooved troughs ramps (for elements having the form of rings, pipe between the machine tools (for balls and rollers), automatic arms (for elements having the form of rolls).

26. Planning of the Equipment

The planning of the equipment of automatic lines is predetermined in a considerable extent by a number of positions - working, checking and idle, and also by the number of simultaneously-treated elements and the method of their transport. Depending on these factors the planning of the machine tools and transport means of automatic lines of aggregated machine tools may be carried out for the planning of the automatic in several variants, after which the plan can no longer be changed.

27. Technico-Economic Effectiveness of Automatic Lines

For the planning and execution of an automatic line, it is necessary to assure the attainment of a greater technico-economic effectiveness in comparison with the nonautomated technological process. An automatic line has the following advantages:

- 1) Higher productivity;
- 2) Considerably smaller number of service personnel;
- 3) Stability and improved quality of the treatment;
- 4) Smaller cost of treatment of elements;
- 5) Smaller production area;
- 6) Rhythmic output of products;
- 7) More rapid depreciation of capital investment;
- 8) Convenience of servicing, assurance of centralization of control.

28. Examples of Executed Automatic Lines and Works

By way of example, the following from a number of operating automatic lines may be mentioned.

Automatic line for treatment of heads of cylinder blocks of tractor engines

(Fig.87).

The line has seven working positions, 134 simultaneous-acting spindles, 20 electric motors with a total power of 212 kw; the length of the line is 15.7 m, the working beat 3.5 min; the productivity of the line is 17 heads per hour.

The line is composed of the following aggregated machine tools:

- 1) 9-spindle horizontal drilling machine Type A241;
- 2) 4-spindle horizontal boring machine Type A242;
- 3) 30-spindle horizontal drilling machine Type A243;
- 4) 22-spindle horizontal drilling machine Type A244;
- 5) 17-spindle horizontal drilling machine Type A245;
- 6) 8-spindle horizontal boring machine Type A246;
- 7) 13-spindle thread-cutting machine Type A247;
- 8) 8-spindle horizontal boring machine Type A248;
- 9) 4-spindle inclined drilling machine Type A249;
- 10) 7-spindle horizontal drilling machine Type A250;

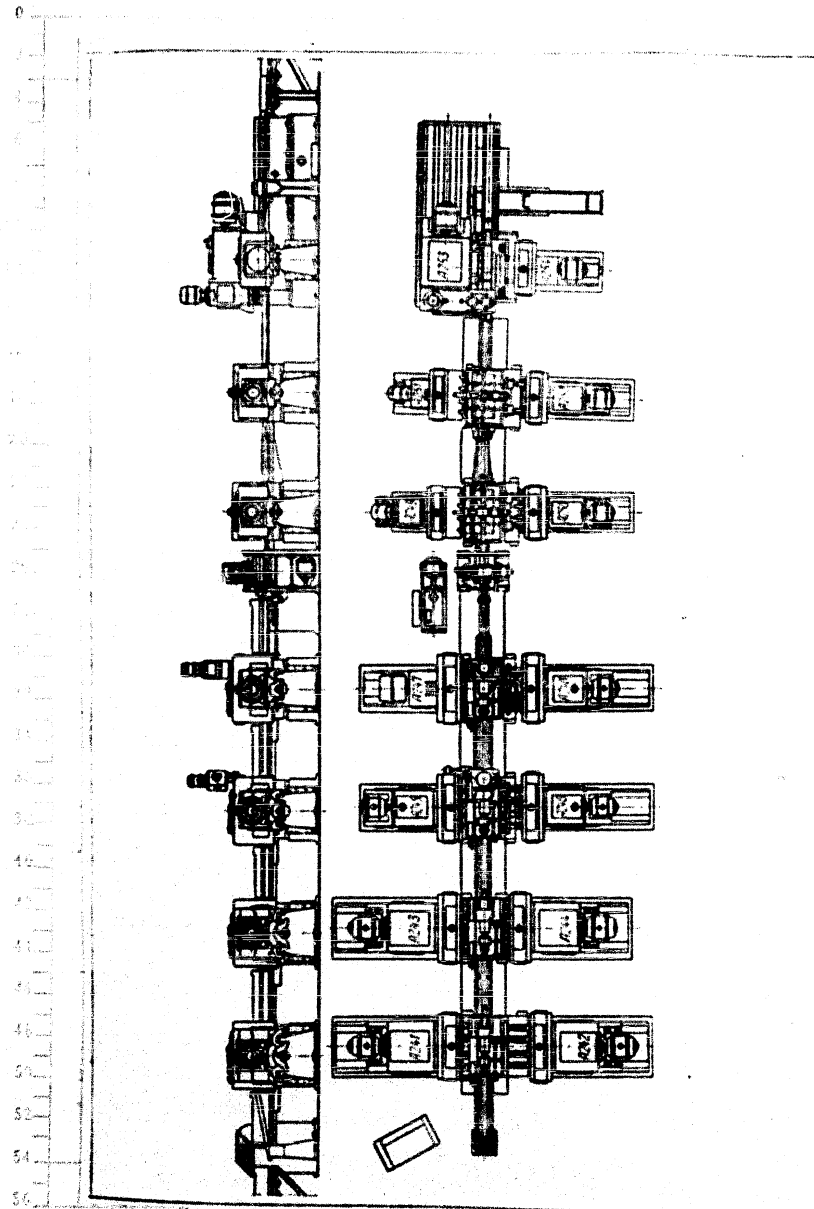


Fig. 87 - Automatic Line for Treatment of Heads of Cylinder Blocks of Tractor Engines

- 11) 4-spindle inclined threading machine Type A251;
- 12) 2-spindle horizontal boring machine Type A252;
- 13) 1-spindle vertical milling machine Type A253;
- 14) 5-spindle horizontal threading machine Type A254.

In each working position, two machine tools are located opposite each other for treating the element simultaneously on two sides. Between the fourth and fifth positions the element is turned 90° with the help of an accessory. All of the accessories serving for fixing and fastening the element in the working positions are brought into action from a central hydraulic station.

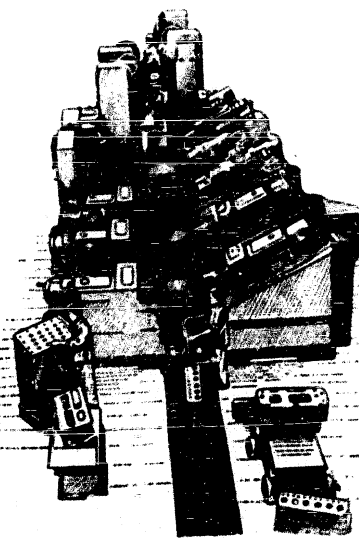


Fig. 88 - Automatic Line for Treatment of
Cylinder Blocks of Truck Engines ZIS-150
(First Section) on Loading Side

Machine tools serve for carrying out the following operations:

Automatic line for treatment of cylinder blocks of truck engines ZIS-150 (Figs. 88 and 89).

The line consists of four individual sections; the total number of machine tools for all of the sections is 45.

The first section, carrying out the treatment of 99 openings on three sides of the cylinder blocks, consists of 16 aggregated machine tools (four vertical, six horizontal and six drilling-boring and thread-cutting machines) on which 224 spindles work simultaneously.

All of the machine tools and apparatuses are driven by 20 electric motors with a total power of 85 kw; the length of the line is 17.2 m. The ma-

0 1) Drilling deep holes, removing facets and cutting threads in upper plane of block;

2) Drilling holes and cutting threads in plane opposite the plane of the distributor for fastening the lid of the valve case of the collector, trimming the intake ducts, finishing the lugs at the openings under the control pins of the guide-push rods;

3) Machining the openings and faces under the distributor, drilling two openings and threading them.

The block is based on the lower plane and two installation holes, and is held in position hydraulically by levers and an eccentric mechanism.

The total time of machining each block at all the work positions is 15 min; the conveyor interval is 2 min (for all sections). Thus a machined block leaves the production line every two minutes.

The control desk is connected with all the machine tools and mechanisms on the line.

The line is served by three operators. A total of 56 operators is required to machine the same number of blocks on universal machine tools.

The second section consists of four double compound machines and has 57 simultaneously operating spindles, and 10 electric motors with 46.1 kw total power. The length of the line is 7.41 m.

The machine tools of the line perform the following operations:

- 1) Drilling and countersinking all openings for the attachment parts;
- 2) Threading the front and rear faces of the cylinder block
- 3) Drill going through longitudinal oil canal;
- 4) Preliminary countersink hole below camshaft;
- 5) Preliminary bore excavation in first main bearing of block.

For the execution of these operations, the block lies on the transporter transverse to the line of movement.

The third section consists of 14 aggregated machine tools with 250 spindles in all; the power of the electric motors is 78 kw; the length of the line is 17.2 m.

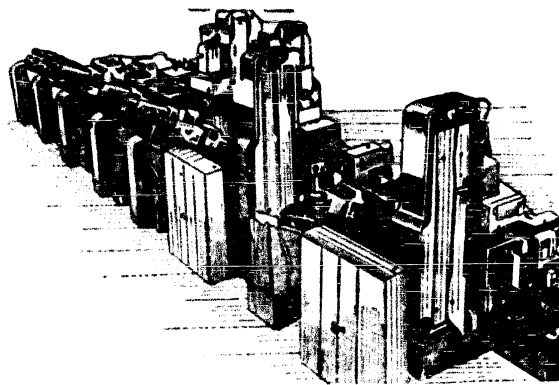


Fig.89 - Automatic Line for Treatment of Cylinder Blocks of Truck Engines ZIS-150 (First Section) on Unloading Side

The machine tools of the line fabricate all of the holes in the lower plane of the block and on the side of the distributor.

The fourth section (Fig.90) has seven one-sided aggregated machine-tools with 67 spindles, driving by ten electric motors with a total power of 43.7 kw; the length of the line is 15.25 m. The line carries out the complete processing of the holes in the block and cuts the threads in the seven holes on the side of the fastening of the distributor.

Automatic works of automobile pistons (Fig.91).

This automatic works is the first in the world practice in which complex automation of the whole process of the production of the complicated product - piston exists, beginning with the casting and ending with the packaging. To the Soviet Union belongs the priority in the creation of such a works, where the whole production process is complexly automated, in which the workers are occupied with the

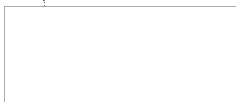


Fig. 90 - Automatic Line for Production of Cylinder Blocks of Engine of Truck ZIS-150 (Four Sections)

0 - Automatic line for production of cylinder blocks of engines
a) Position 6; b) Position 5; c) Position 4; d) Position 3; e) Position 2; f) Position 1;
g) Unloading of elements; h) Loading of elements; i) Control desk

processes of adjustment and control only.

The automatic works produces 11 type sizes of piston, of which four sizes of pistons for trucks ZIS-150 (one normal and three replacement); and seven sizes of pistons for trucks GAZ-AA (one normal and six replacement).

The pistons are made of aluminum alloy AL-25; the castings must have a hardness $H_B = 115-140$ and a limit of strength for stretching of not less than 17 kg/mm^2 ; the cylindrical surface of the skirt is tinned.

The pistons of the given type size must have the same weight with a permissible deviation of $\pm 4 \text{ gm}$ (0.5% of the weight of the piston) for pistons ZIS-150, and for pistons of GAZ-AA of $\pm 2 \text{ gm}$ (0.35% of the weight of the piston). The pistons are sorted into groups: according to the diameter of the skirt through 20 mk, according to the dimension of the diameter of the skirt through 20 mk, according to the dimension of the hole below the pin through 2.5 mk. Conicity of the skirt is permissible between 0.01-0.05 mm, ovality up to 0.15 mm. The hole below the piston pin may deviate from true cylindrical form by not more than 3 mk.

The automatic works carries out automatically in a particular sequence, the following stages of the production process:

- 1) Periodical charging of melting furnace;
- 2) Melting, refining and deslagging of aluminum alloy;
- 3) Periodical measured feeding of molten alloy to permanent molds;
- 4) Opening the mold, removing the casting, and readying the mold for the next

pouring;

- 5) Transporting the casting to the aggregate for cutting off the pouring

channel;

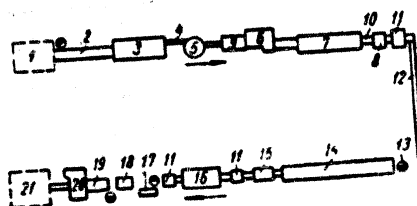
- 6) Cutting off the pouring channels and returning them to the charging platform of the melting furnace for remelting;

- 7) Bringing the casting on the conveyor to the furnace for heat treatment;

- 8) Heat treatment of the casting followed by cooling to room temperature;

9) Bringing the castings into the necessary position and feeding them to the press for verifying the hardness;

10) Verifying the hardness of the castings and rejecting the defectives;



11) Transporting the castings to the line for mechanical treatment;

12) Mechanical treatment on the automatic machine line, including means for transporting the elements and automatic checking;

13) Transfer to the automatic machine for matching the weight of the piston;

14) Matching the weight of the piston;

15) Transfer to the aggregate for finish grinding;

16) Finish grinding of the outer surface;

17) Transfer to the aggregate for tinning;

18) Tinning the surface of the pistons, and unloading them from the aggregate for tinning;

19) Finish treatment of the hole below the piston pin with a precision higher than first class;

20) Washing and drying the pistons with cooling to room temperature;

21) Finish checking of geometrical form and dimensions, eliminating rejects,

Fig. 91 - Scheme of Automatic Works for Production of pistons of Automobile Engines:

1 - Supply of ingots; 2 - Apron Transporter;

3 - Melting furnace; 4 - Trough; 5 - Rotary casting machine; 6 - Machine for

trimming castings; 7 - Furnace for heat treatment; 8 - Brinell press; 9 - Cooling

chamber; 10 - Transporter; 11 - Bunker; 12 - Slideway; 13 - Operator; 14 - Auto-

matic line of machine tools; 15 - Aggregate for matching by weight; 16 - Aggregate

for tinning; 17 - Machine for finish-treatment of hole below piston pin;

18 - Washing machine; 19 - Checking-sorting automatic machine; 20 - Packaging

machine; 21 - Piston storage

0 sorting to groups by size, marking and transferring to packaging machine;

22) Coating the pistons with anticorrosive lubricant, wrapping them in water-impermeable paper, making up sets of pistons, packaging sets in cardboard boxes, delivering boxes for shipment.

All of the auxiliary processes are automated. The cuttings from the treatment of the pistons are cut up, and removed from the shop by a special transporter.

Remote observation of the operation of the aggregates and continuous automatic registration of the principal production indices occurs from the dispatcher's desk equipped with a signal panel.

In some cases, between working aggregates, buffer means are present, automatic to the extent required, for receiving, keeping and delivering the elements in process to the respective treating operations.

The aggregates of the whole works are connected with each other by a system of electric controls, and equipped with blocking means, disconnecting the corresponding aggregate at deviation from the normal course of the process. For this, simultaneous with the stopping of the aggregate, over it a light-signal device is automatically connected, and this signal is simultaneously doubled at the dispatcher's desk.

A number of devices carrying out automatic regulation of some of the parameters of the production process are also present: temperature, chemical composition, pressure, etc.

The mechanical treatment of the pistons consists of the following technological operations:

- 1) Treatment of base place - undercutting of face of piston apron, drilling and reaming two holes simultaneously of two pistons on aggregated machine tools;
- 2) Preliminary countersinking of opening below piston pin and centering of base on bottom of piston on aggregated machines simultaneously with four pistons;
- 3) Preliminary facing of outer cylindrical surface, undercutting face of

bottom of piston, and undercutting excavation below piston ring on aggregated machine tools simultaneously with four pistons;

4) Milling horizontal slots on aggregated machines simultaneously with four pistons;

5) Finish facing of cylindrical surface, undercutting face of bottom, slotting below piston ring, and chamfering on aggregated machines simultaneously with four pistons;

6) Checking width of channels and height of each piston on automatic device;

7) Drilling ten lubricating holes in each piston on special automatic machines simultaneously with four pistons;

8) Preliminary profile grinding of cylindrical surface at stepped shoulder on aggregated machines simultaneously with four pistons;

9) Milling inclined slot in piston skirt and marking central boss for its removal on the aggregate of machines simultaneously with four pistons;

10) Matching weight of piston by boring special head on special aggregate simultaneously with two pistons (removing surplus metal on inner side of skirt);

11) Centerless profile grinding of shoulder and finish grinding of skirt of piston on automatic centerless grinding machine simultaneously with four pistons;

12) After the tinning the final treatment of the hole below the piston pin is carried out on aggregated multispindle machines by diamond boring and reaming, and also the excavation of the slot in this hole below the locking ring.

The automation of such diverse technological processes of mechanical treatment is realized with specially-designed, highly-productive equipment, including the following:

1) Automatic machine line, carrying out various operations of mechanical treatment of the pistons;

2) Automatic system of intermachine transport for transferring the pistons from the automatic machine for matching according to weight and its loading, and

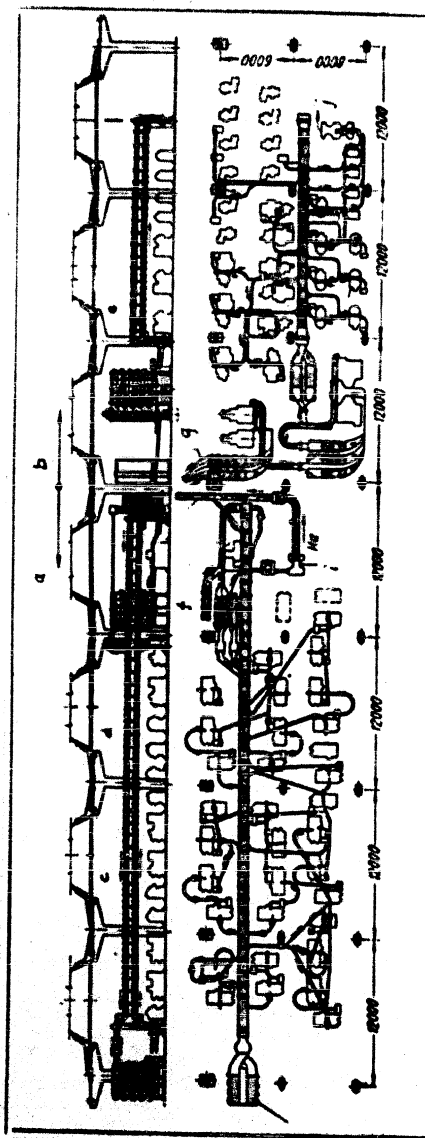


Fig. 92 - Automatic Shop of Antifriction-Bearing Works

- a) Lathe department; b) Grinding department; c) Route N3; d) Flow; e) Route N4;
f) Route N2; g) Heating; h) Accumulator of rough rings; i) To heat treatment; j) To assembly

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also for transferring the pistons from this machine to the centerless grinders;

3) Center grinding machines for final profile grinding of skirt and shoulder of four pistons simultaneously;

4) Aggregate for final treatment of hole below piston pin without a precision higher than first class without adjustment for regulation and replacement of tools in the course of at least one shift;

5) Per shift of the automatic works there are seven qualified adjusters and three operators (three in the casting and heat-treating and seven in the mechanical section).

The technico-economic effectiveness of the work of the automatic works is characterized relative to the indices of ordinary mass production by the following data: the total number of workers of all categories is decreased 4.2 and the operators and adjusters 5.3 times; the number of occupied operators is decreased 16 times and labor expenditures 5.3 times; the production cycle is decreased two times, considerably accelerating the turnover of the working capital.

Automatic shop of antifrictional-bearing works (Fig.92). In this automatic shop the complete cycle of treatments of the rings of ball-bearings of various sizes is carried out, including lathing, thermal and grinding operations. The shop consists of groups of automatic lines of machine tools, with special accessories, which load and unload the elements, start and stop the machines, put in and take out the supports. At the beginning of each line an "accumulator" is located, for the supply of blanks for one working shift; each machine tool has its allotment of elements.

From the master transport routes special lift-transport means feed the rings to the loading bunkers at the machine tools; sliding the rings along ramps.

The machine tools can work independently of each other or by groups.

The technico-economic effect of such an automatic shop is fairly high; the yearly output per machine and per worker is higher, the production cost lower and, the cycle shorter.

CHAPTER V

PLANNING OF ASSEMBLY SHOPS

29. Starting Data for Planning of Assembly Shops

The basis for the planning of the assembly shop is the production program of the shop, prepared on the basis of the production program of the works, with annexed specifications on the aggregates and elements arriving in the shop, drawings on the assembled and general form of the aggregates and elements, technical conditions on the acceptance and testing of the products.

The production program of the assembly shop must contain the names of the aggregate and machines to be assembled, the weight of each aggregate, the yearly output, the explicit number of aggregates (or sets), and the weight in tons including spare parts.

The specifications of the elements and aggregates arriving in the assembly shop must stipulate their name, identification number, number per product, and shop from which they arrive in the assembly shop.

The drawing of the assembled and general form necessary for formulating the technological process of assembly must show the dimensional tolerances, the particular location of the elements relative to each other, the constructive clearances, and also any special requirements with respect to the assembly of the machine.

The planning of assembly shops of small-series and series productions, when the production program of the shop consists of a long and diverse list of products, is done according to the reduction program.

For preparing the reduction program all of the machines to be assembled are divided into groups according to constructive and technological similarity. In each of the groups the most typical machine, which becomes the calculated representative of all of the machines entering into the given group, is selected. For this calculated machine (representative) the technological process of assembly is formulated with standardization of the times for each of the assembly operations.

The labor expenditure on the assembly of the machines entering into the given group is determined according to the coefficient of reduction. The coefficient of reduction equals the ratio of the labor expenditure on the assembly of the calculated machine to the labor expenditure on each of the machines entering into the given group.

This coefficient is established in dependence on the relative weights and overall dimensions of the machines, the seriality of the output, and the complexity of their assembly.

The production program is prepared according to the form shown for mechanical shops (Table 3).

In the planning of an assembly shop of series production, according to a reduction program, the technological process with the technological chart is formulated only for the calculated machine, while for the remaining machines operations lists are prepared showing the general course of the technological process, with particular expenditures of time according to the coefficient of reduction.

In the planning of assembly shops of unit production no technological chart of the assembly is formulated, and only the operations are prepared.

The planning of shops of flow-mass and flow-series production is done according to the flow program, with formulation of the technological chart and standardization of the times for each of the operations for both complete and aggregate assembly.

The composition of the assembly shop is determined by the character of the manu-

factured products, the technological process, the size and organization of the production.

In unit, small-series and series production, aggregate and complete assembly is carried out in an assembly shop or in the assembly department of the mechanical-assembly shop. In large-series and mass production the aggregate assembly of the products is carried out at the end of the flow line or in a department of the mechanical shop in which the elements of the given aggregate are treated. In this case, we have the principle of a complete cycle of production of the given aggregate including treatment of the elements and assembly of the aggregate. In automobile- and tractor-building, the production usually proceeds according to this principle.

The composition of an assembly shop includes:

- (a) Production departments or sections;
- (b) Auxiliary departments or sections;
- (c) Service rooms;
- (d) Living quarters.

The production departments (or sections) includes the departments (sections) of mechanical treatment (in unit and small-series production), of aggregate and complete assembly, of painting, drying, polishing, testing, and packaging of the finished products.

The auxiliary departments or sections include: the section of technical checking, intermediate storage of elements and aggregates, storage of auxiliary materials, tool-distributing storeroom, workshops of shop mechanics, shipping, sometimes storage of finished products.

The service rooms comprise the rooms for the technical part of the shop, the checking and administrative-technical personnel.

The composition of living quarters includes rooms for eating, lockers, washing, relaxation, toilet, etc.

30. General Principles of Planning of Technological Process of Assembly

The elements arrive for assembly of the machines in the assembly shop after treatment on the machine tools in the mechanical shop. If an element is treated according to final calibration and the machine operations constitute the final stage of treatment for giving it the necessary form and dimensions, such elements are regarded as interchangeable with each other, and go directly to the assembly through the intermediate storage. If the elements arrive for assembly without any sorting or selection from other elements by which they are accompanied, and if they go into place with the necessary and sufficient fit without any adjustment and matching, such an assembly is called assembly with complete interchangeability of the parts; at such an assembly there can be organized a flow assembly process. This principle of assembly is employed in large-series and mass production.

In assembly the elements must go into place without matching, but selection according to dimensions is called assembly with incomplete interchangeability.

Selection of elements takes place by size for assuring the necessary fit at the joining either from the elements arriving for assembly or, as is more frequently the case, by preliminary sorting of the elements into size groups. This assembly is called selective; it is employed in large-series and mass production.

Assembly may also take place with incomplete interchangeability by the employment of rigid or regulating compensators of the given size of chain - joint; liners, rings, bushes or one of the available elements can serve as rigid compensators, whose dimensions are matched by supplementary treatment. This method of assembly is employed in unit, small-series and series production.

Assembly leads to the necessity of treating the elements in the mechanical shop at narrower permissible deviations from the theoretical dimensions with complete interchangeability of the elements, which increases the cost of the mechanical treatment but decreases the cost of the assembly.

The assembly of elements possessing incomplete interchangeability gives the

possibility of treating them in the mechanical shop at a greater permissible deviation from the theoretical dimensions in comparison with elements possessing complete interchangeability at this the cost of the assembly work is increased because the elements must be selected and sorted into size groups.

In unit and small-series products, the elements must undergo hand treatment for receiving the final form and dimensions and for matching into place after mechanical treatment carried out without employment of limit gauges. In this case, before assigning the elements, they are subjected to final hand treatment and finishing, after which they are fitted into place by filing, scraping, lapping, grinding, etc.

Many elements are put together with other elements to make up aggregates (groups) before assigning them to their place in the assembly of the whole machine. The aggregates may consist either of individual elements only or of individual elements which have first been joined together before putting them in the aggregate. Such preliminarily joined (before being made up into aggregates) elements for simpler combinations, called subaggregates (subgroups). The combination of several units forms an aggregate or mechanism; the first-named are employed, for example, in tractor-building. This combining is done either directly with the elements entering into the unit or with the help of special elements serving for making up the unit.

The whole product - machine is assembled from aggregates (mechanisms), units and individual elements.

Each of the mentioned combinations constitutes a structural-assembly unit of one or another degree of complexity. In the above-described sequence of making up the subunits (subgroups), the structural-assembly units will be of the first degree of complexity; bundles (groups) are structural-assembly units of the second and aggregates (mechanisms) structural-assembly units of the third degree of complexity. The whole product, depending on its complexity, can be analyzed into a more or less large number of structural-assembly units.

Accordingly the assembly process consists of the following successive stages:

1. Hand treatment and matching; this stage does not exist in mass production, it is used to a small extent in series production; it is principally employed in unit and small-series production.
2. Bundling (or preliminary) assembly - joining elements into subbundles (subgroups), bundles (groups), aggregates (mechanisms).
3. Complete (or final) assembly - assembly of the whole machine.
4. Regulation - adjustment and testing of the correctness of the interaction of the parts of the machine.

The following fundamental operations may enter into bundling - and complete-assembly: a) fastening of the elements; b) assembly of stationary elements; c) assembly of moving elements; d) assembly of rotating elements; e) assembly of motion-transmitting elements; f) marking for assembly (at individual and small-series production); g) suspending and balancing bundles of elements; h) putting on the housing, frame, plate of the body.

A graphic scheme should be constructed for graphic representation and convenience of planning and execution of the assembly process. An example of such a scheme is represented in Fig.93. The scheme shows the elements of which the simplest combinations are composed - the subbundles (subgroups); the scheme also shows the subgroups of which the bundles (groups) are composed. In addition the bundles and elements composing the aggregates (mechanisms) going into the complete assembly of the machine are given. In the scheme, at the circles denoting the elements, the drawing numbers of the elements are noted; in the denotations of the bundles, the assembly-drawing numbers of the bundles, and in the denotations of the aggregates (mechanisms) the identification letters (or numbers) of the aggregates (mechanisms), are noted.

In Fig.94 the technological scheme of the assembly of the tailstock of a multi-cutter lathe is shown, and in Fig.95 (compare inlay at end of book) the technologi-

cal scheme of the assembly of an automobile engine is constructed in a different form.

The finished products may be divided into a larger or smaller number of intermediate assembly combinations depending on the degree of complexity of the structural-assembly units put out by the works, and must be named in correspondence with their degree of complexity.

If the machine has a complicated construction, its representation in the total assembly scheme will be difficult because of the large number of elements and combinations. In such cases, therefore, schemes of assembly of the individual bundles and aggregates should be prepared, and the scheme of assembly of the whole machine from the bundles, aggregates and individual elements.

The division into aggregates, bundles, subbundles and individual elements depends on the constructive particularities of the machine, by its bundle combinations and details. For each type of machine this division may have its particular character; general rules on the division of the various machines into individual combinations cannot be given because, as already stated, this division depends on the construction of the machine, it is moreover, tentative, and is applied only to the given type of machine.

The division of the construction of products into individual assembly units should be guided by the following considerations:

- (1) It must be desirable to be able to distinguish the combinations in the assembled unit from each constructively and technologically;
- (2) It must be brought to the total assembly the smallest possible number of individual elements;
- (3) The total assembly must be maximally relieved of the execution of small assembly combinations and various auxiliary manipulations;
- (4) To the total assembly there must come the largest possible number of preliminarily-combined assembly-units;

(5) There must be assured the proper technological connection between and sequence of the assembly operations.

The productive capacity of the assembly shop depends on the time of the stay of the machines at the assembly place: the smaller the time, the greater the produc-

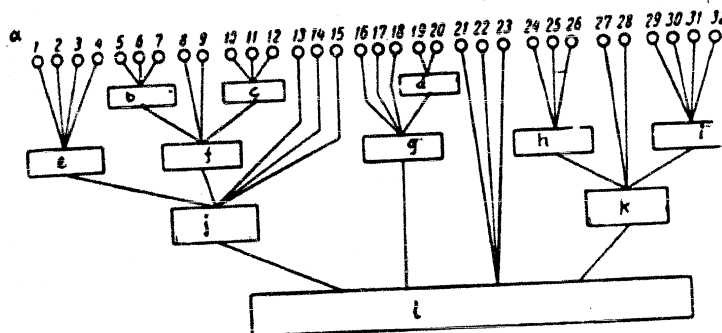


Fig. 93 - Scheme of Assembly Process

a) Element; b) Subbundle; c) Subbundle; d) Subbundle; e) Bundle I; f) Bundle II; g) Bundle III; h) Bundle IV; i) Bundle V; j) Aggregate (mechanism); k) Aggregate (mechanism); l) Complete assembly of product

tive capacity. Shortening of the staying time of the machines at the assembly place (stand) is obtained by:

1. Treatment of elements according to the principle of interchangeability, thereby eliminating hand treatment and matching of dimensions of elements in place.

The employment of the principle of interchangeability does not necessarily mean that the treatment of the elements must take place only with a high precision; interchangeability can also be obtained at a comparatively low class of precision, so that the machines which do not require a high class of precision of the latter according to their construction, character and purpose should not be striven for be-

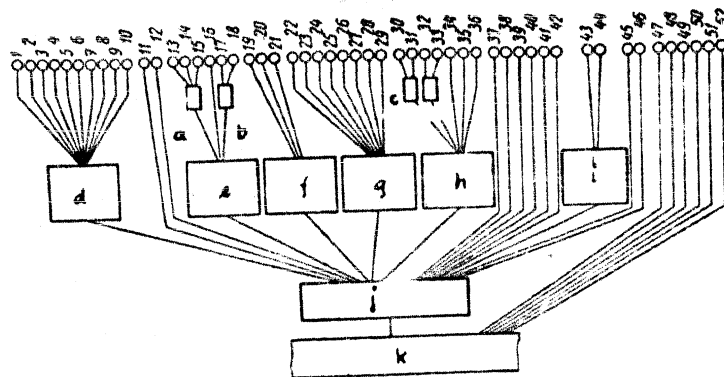


Fig.94 - Technological Scheme of Assembly of Tailstock of Multicutter Lathe

- 1) Bush (1 piece); 2) Bearing OST 6124 (2 p.); 3) Bush (1 p.); 4) Bearing OST 7219 (1 p.); 5) Ring (1 p.); 6) Spring (3 p.); 7) Bush (1 p.); 8) Bearing 6121 (1 p.); 9) Disk (1 p.); 10) Nut (2 p.); 11) Packing (1 p.); 12) Center (1 p.); 13) Spindle; 14) Nut (1 p.); 15) Setscrew (2 p.); 16) Screw (1 p.); 17) Trapeziform screw (1 p.); 18) Cylindrical pin (1 p.); 19) Spindle cover (1 p.); 20) Packing ring (1 p.); 21) Cylindrical-head screw (3 p.); 22) Tailpiece body (1 p.); 23) Spline (1 p.); 24) Countersink-head screw (2 p.); 25) Cylindrical-head screw (4 p.); 26) Bolt (3 p.); 27) Disk (3 p.); 28) Setscrew (2 pieces); 29) Setscrew (1 p.); 30) Clamping handle (1 p.); 31) Ball (1 p.); 32) Fork (1 p.); 33) Conical pin (3 p.); 34) Expansion bolt (1 p.); 35) Fork axle (3 p.); 36) Setscrew; 37) Nut (1 p.); 38) Clamping ring (1 p.); 40) Flange (1 p.); 41) Cylindrical-head screw (3 p.); 42) Spline (1 p.); 43) Flywheel (1 p.); 44) Handle (1 p.); 45) ; 46) Nut (1 p.); 47) Distance piece (1 p.); 48) Distance piece (1 p.); 49) Distance piece (1 p.); 50) Disk (2 p.); 51) Nut (2 p.); 52) Screw (2 p.).
- a- Subbundle; b- Subbundle; c- Subbundle; d- Bush bundle; e- Spindle bundle; f- Cover bundle; g- Tailstock-body bundle; h- Clamping-handle bundle; i- Flywheel bundle; j- Tailstock (mechanism); k- Complete assembly of multicutter lathe.

cause in this case a high precision only increases the production cost.

2. As much as possible use of preliminary assembly of elements to bundles and of bundles to aggregates outside the place of assembly of the whole machine; for the assembly of elements to bundles it is convenient to use templates, fit plates, models.

3. In avoiding idleness of the assemblers, assuring timely delivery of elements, bundles, materials, tools and accessories to the assembly place.

4. Widest possible employment of special accessories and tools for decreasing expenditure of time on execution of assembly operations.

5. Most precise establishment of the time norms for all of the assembly work depending on the character and methods of execution of the assembly operations.

6. Employment of the flow method of assembly for shortening the time for the assembly of the whole machine to the extent that this is possible according to the character of the production.

For decreasing the hand work, the process must be mechanized as much as possible by the use of various mechanisms. The use of such mechanisms considerably facilitates and accelerates the manipulations of the workers, improves the quality of the work, and enables it to be performed by workers of lower qualifications.

Mechanisms replacing hand work are used, for example: portable electric grinding machines; electric and pneumatic drilling machines; mechanical machines for lapping valves (instead of hand lapping); mechanical scrapers; electric chisels, hammers, screwdrivers, planes; pneumatic chisels and hammers; dynamometric wrenches; riveting machines for noiseless riveting - suspended and stationary pneumatic, pneumohydraulic, electrohydraulic; presses - hand, mechanical (crank), pneumatic, hydraulic - for pressing-on bushes, pins, pulleys, flywheels, cogwheels, etc.

In exactly the same way, it is also possible to facilitate and accelerate the execution of assembly operations by the use of special accessories. This can include:

Accessories for adjusting and joining elements;
 Accessories for fastening constituent elements of assembly bundles;
 Demounting accessories for demounting cogwheels, pulleys, flywheels from shafts,
 for demounting bushes from cylinders;

Accessories for lifting elements at assembly - yokes, grabs, etc;
 Rotating accessories serving for rotating shafts at assembly of internal-
 combustion engines, steam engines, compressors;

Accessories for displacing the product being assembled, for example, for turn-
 ing cylinder blocks, automobile frames;

Checking accessories, for example, for checking the perpendicularity of the
 axis of the piston to the axis of the piston pin, the correctness of the position
 of the cam of the distributor shaft, the correctness of the cylinder axis, etc.;

Accessories to measuring implements giving access to inaccessible places;

Accessories for regulating engine valves in the form of disks with graduations;
 accessories for determining dimensions of compression chamber;

Accessories for preliminary compression of springs, etc.

The relative time expended on the assembly work and the mechanical treatment,
 and also relative times expended on the individual stages of the assembly process,
 depends on the form of the production and the methods of assembly. The times
 for the assembly work in percent of the times for mechanical treatment are
 approximately:

at individual and small-series production	40-50%
at medium-series production.....	30-35%
at large-series production.....	20-25%
at mass production.....	less than 20%

As already stated, it must be sought to decrease the time for hand work, which
 is used to a considerable extent at individual and small-series production, and
 which is not always avoidable at series production.

It is also necessary to use preliminarily-bundled assemblies and to send to the total assembly the smallest possible number of individual elements, for shortening the time for the total assembly at the stand.

Some approximate expenditures of time for individual stages of the assembly process at series production of machines of medium size are presented in Table 17.

Table 17
Approximate Relative Times for Individual Stages of Assembly Work at
Series Production.

<u>Stage of Mechanics Assembly Work</u>	<u>Relative Time in %</u>
Hand treatment of elements	up to 10
Bundling assembly of elements	40-50
Total assembly at stand	50-60

As stated above, the technological process of assembly consists of combining elements to bundles and of bundles and individual elements to whole machines. In this connection the whole assembly process is divided into individual successive stages, which are in turn divided into individual successive operations, transitions, parts, methods. The sequence of operations may be left somewhat flexible.

The elements, if according to the character of the production after their mechanical treatment, require some final finishing treatment by hand for giving them the necessary dimensions and form, such work must precede the assembly.

In formulation of the technological process of assembly, a description of the character of the work and the method of its execution must be given for each of the operations, transitions and other parts of the assembly process; the necessary tools and accessories must be indicated, determining the required amount of time, the number of workers, and their qualifications. The times required for execution of the individual operations of assembly of bundles and sets, and the moments of their delivery together with the elements to the place of total assembly, must be established

in such a way as to assure uninterrupted procedure of the assembly process. Accordingly, the technological process of assembly determines the duration of the assembly of the products, the number of workers on the individual operations and on the whole assembly, the time of the assembly work of all of the workers, and the time points of the delivery of the elements, bundles and sets.

A. Determination of Time Norms

Among the fundamental factors entering into the composition of the technological process of assembly is the time for the execution of the respective operation. The structure of the time norms for the assembly operations is analogous to that for machine work. The norms of the piece times for the assembly operations consist of:

- (1) The fundamental and technological times;
- (2) The auxiliary times;
- (3) The times for servicing the working places;
- (4) The break times for physical demands and relaxation.

Relaxation time is only included if it is necessary for counteracting fatigue due to working conditions. The sum of the fundamental and auxiliary times constitute the operative time. The readying-closing time, which is established for whole lots of assembly units and products, and does not depend on the number of pieces in the lots, is also included.

The sum of the piece and readying-closing times per assembly unit (or product) constitutes the calculation time.

In mass production, one and the same operation is repeated on the working places, and no kind of readying-closing work is carried out, a readying-closing time does not enter into the time norms of the workers. The fundamental, auxiliary and readying-closing times are determined, according to standard data, prepared on the basis of study and analysis of experimental time-study data of advanced enterprises in correspondence with the particular organizational conditions of the pro-

duction. The time for servicing the working places and the time of the breaks for physical demands are taken in percentual ratios of the operative time.

In assembly work the time for serving the working places is approximately 2-3% of the operative time, depending on the equipment. The time for physical work demands the same as with mechanical work, that is, at 2% of the operative time.

Analogously to machine work the time norms for assembly work are expressed by the following formulas:

Piece time for assembly of units or products

$$t_{sht} = t_o + t_v + t_{ob} + t_f; \quad (167)$$

Operative time for assembly of units or products

$$t_{op} = t_o + t_v; \quad (168)$$

Time for assembly of lots of units or products

$$T_p = t_{sht}n + T_{o.z} \quad (169)$$

Calculation time per assembly unit or product

$$t_k = t_s + \frac{T}{n}; \quad (170)$$

where t_{sht} is the piece time for the assembly of units or products in minutes;

t_o is the fundamental (technological) time in minutes;

t_v is the auxiliary time in minutes;

t_{ob} is the time for servicing the working places in minutes;

t_f is the time for relaxation and physical demands in minutes;

t_{op} is the operative time on the assembly of units or products in minutes;

T_n is the time on the assembly of lots of units or products in minutes;

n is the number of assembly units or products in the lot;

$T_{o.z}$ is the ready-in-closing time on all of the lots of assembly units or products in minutes;

t_k is the calculation time per assembly unit or product in minutes.

For expressing the time on servicing the working places and for physical demands in dependence on the operative time formula (167) may be represented in the

following form:

$$t_{shf} = t_o + t + (t_o + t) \frac{\beta}{100} + (t_o + t) \frac{\gamma}{100}, \quad (171)$$

or

$$t_{shf} = (t_o + t) \left(1 + \frac{\beta + \gamma}{100} \right), \quad (172)$$

or

$$t_{shf} = t_{op} \left(1 + \frac{\beta + \gamma}{100} \right), \quad (173)$$

where β is the percent of operative time corresponding to the time for servicing the working places.

γ is the percent of operative time for the physical demands and relaxation.

In the planning of assembly shops (particularly of unit, small-series and series productions) the standardization of the assembly works occurs on the basis of practical data of advanced works putting out analogous products, in which these data are corrected for taking into account more-modern technological-methods and improved organizational forms of the production. A precise determination of the time norms on the assembly work takes place on the basis of detailed calculations on the basis of the particular transitions and components.

B. Formulation of the Technological Process of Assembly

The technological process of assembly is formulated in the form of charts, schemes, graphs, which constitute the fundamental calculation documents. Various kinds of chart forms are employed, but often they are greatly simplified, and do not contain all of the factors of the assembly process.

As already noted, the assembly process consists of individual successive stages (assembly of bunches, assembly of aggregates, total assembly of whole machines); for each stage of the assembly the technological process is formulated, divided into operations, transitions, etc. The chart for each of the stages of the assembly work must also be prepared in correspondence with the latter, which may be prepared either for each of the stages of the assembly separately or combined to include all its

stages.

All of the factors composing the technological process are entered in the charts of the assembly work for each of the stages. They must contain:

- (a) Name of the machine;
- (b) Yearly output of machines;
- (c) Number of machines per series;
- (d) Division of the whole job in stages of assembly;
- (e) Indication of required accessories, tools, appurtenances;
- (f) Beat of assembly in time for execution of individual operations;
- (g) Total standard time for all of the work of executing the given operation;
- (h) Classes of qualifications of workers;
- (i) Constructive clearances for joined elements which must be observed at the assembly;
- (j) Detail sketches showing assembly operations, accessories, method of fastening cable or chain for lifting and turning product.

By way of example we present specimens of typical charts of assembly at which form 12 is a simple chart and form 13 is a complex chart.

Table 18 represents an example of a total-assembly chart for gear boxes of metal-cutting machines. The chart contains detail sketches illustrating the process of assembly.

The whole process of total assembly is divided into seven operations carried out at seven machine-tool working-places; the transfer of the products being assembled between the machine tools takes place with rollways. The second operation is carried out at two parallel working places, so that the time for its execution is approximately twice the beat of the assembly process.

The assembly proceeds in the following sequence:

In the first station the drive shaft and the shaft connecting the friction are set in the gear box; in the second, the slotted shaft with elements; in the third,

the intermediate shaft with cogwheel; in the fourth, the friction shaft and shift lever; in the fifth, the spindle is mounted and the first regulation is carried out; in the sixth, the shaft of the change gear is set; in the seventh, the friction body is set and some remaining elements are installed.

Form 12

Operational Chart on Total Assembly

a		f		j					
b		g							
c	d	h		k	l	m	n	o	p
I	1	i							
	2								
	3								
	etc.								
II	1	i							
	2								
	3								
	etc.								
etc.									

a) Name of product; b) Assembly drawing No.; c) Operation No.; d) Transition No.

f) Yearly output; g) Number of pieces; h) Plan of assembly; i) Time for operation;

j) Assembly chart No.; k) Accessories; l) Tools; m) Time in hours; n) Number of workers; o) Total personnel; p) Class of work.

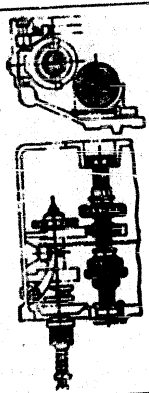
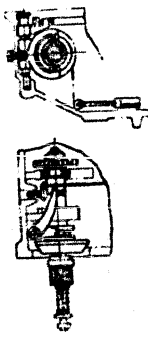
31. Forms and Methods of Assembly; Calculation of Equipments

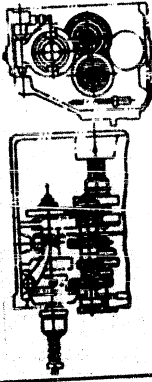
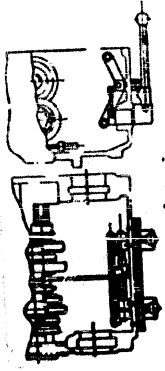
The assembly is divided into two forms according to the form of work organization: stationary and moving.

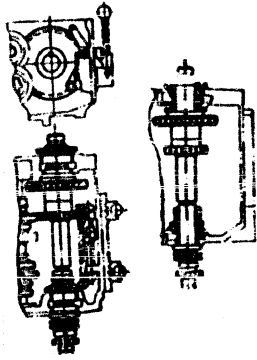
Stationary assembly is characterized in that it is performed by groups of workers (teams) at the same fixed place, to which the elements and assembly units are fed.

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STAT

DETAIL SKETCH OF ASSEMBLY	DELIVERY TO ASSEMBLY		CONTENT OF OPERATION	TOOL	CUTTING	WEAVING	FINISHING	NUMBER OF WORKERS	UNIT OF MEASURE	L-R
	IDENTIFICATION	NAME OF ELEMENT								
	28-OP-153	BOX BODY OIL FILTER DRIVE SHAFT BEARING CONICAL PIN SLIDE BLOCK FRICION. CONNECTING SHAFT	SET DRIVE AND FRICTION. CONNECTING SHAFT PUT OIL FILTER (GM. 2) IN BOX CASE (GM. 1) TAKE GEAR 61214 FROM DRIVE SHAFT (CONPLEX 1). PUT DRIVE SHAFT IN CASE AND FASTEN MARK, DRILL AND REAM CONICAL HOLE OF DIAMETER 10 X 100 FASTEN BUSH (GM. 5) WITH CONICAL PIN TO 100 K12-8 PUT SLIDE BLOCK (GM. 6) IN CASE, SELECT FRICTION SHAFT, PLACE BY GROUPS LIGHTEN STOPPER 1/4-DC	WRENCH 32 /OST 95A LEAD HAMMER NORMAL TOOL SMOOTH FILE 200/OST 31 HAMMER 400/OST 4850 WRENCH 16/OST 95A	DRILL DIAMETER REAMER S. 15-4					
	612174 612245 1-DC-151	SPINDLE SHAFT COVER SPINDLE SHAFT SLEEVE PIN BEARING WASHER SCREW COVER SCREW PACKING GEAR OF SLOTTED SHAFT	SETTING SPINDLE SLEEVE AND GEAR TAKE FROM SP. SHAFT PUT (GM. 8) BUSH 612119 BUSH IN PLACE OF SP. SHAFT ADJUST ELONG 101-153. 101-153 TO 10. 10. 22. OST 216 OST 216 PUT COVERS 2114. 612037 WITH PACKINGS 612244 AND TIGHTEN BOLT MB-50 OST 218 FASTEN SLEEVE 2118 WITH SCREW AND ELASTIC RING	LEAD HAMMER 200/OST 4859 SMOOTH FILE 200/OST 310 SCREWDRIVER 100-11						
	612037 S. 15 OST 2022 10 DP-153 B 92-K7-10 MB-15 OST 316 612214 MB-50 OST 218 612244									

DETAIL SKETCH OF ASSEMBLY	DELIVERY TO ASSEMBLY		CONTENT OF OPERATION	TOOL		NAME AND GRADE OF MATERIALS
	IDENTIFICATION	NAME OF ELEMENT		MECHANICS ASSEMBLY	CUTTING	
	25 DP-153 612182 NO. 15 OST 218 NO. 50 OST 218 61224	INTERMEDIATE SHAFT BLANKING COVER PACKING	SETTING INTERMEDIATE SHAFT SELECT INTERMEDIATE SHAFT (ON 13) PUT SHAFT IN CASE, ADJUSTING GASKETS, 612158, 612127, 612138, 612158, 612128, 612130 PRESS ON BEARING TS DP-153 AND GEAR WITH 612122, AND FASTEN WITH NUTS FASTEN GEAR 612127 WITH SCREW NO. 15, OST 218 SET COVERS 612158, 612015 PUT IN PACKINGS 612244 AND SECURE WITH BOLTS NO. 50, OST 218	LEAD HAMMER HAMMER 600/OST 4859 WRENCH 22/OST 954 SCREWDRIVER (NO. 1) 612158 (COPPER, 612158)		
	612182 MID-40 OST 218	FRICTION-CONNECTING SHAFT CLAY SCREW SWITCHING LEVER RIGHT-HAND LEFT-HAND	SETTING SHAFTS OF FRICTION- AND LEVER SWITCHES SET FRICTION-CONNECTING SHAFT (ON 134) IN BOX CASE PUT IN CLAY AND SCREW TOGETHER WITH FRICTION-CONNECTING SHAFT	LEAD HAMMER HAMMER 300/OST 4859 DRIFT SCREW-DRIVER (NO. 1)		

DETAIL SKETCH OF ASSEMBLY	DELIVERY TO ASSEMBLY		CONTENT OF OPERATION	TOOL	CUTTING	FINISHING
	IDENTIFICATION ELEMENT	NAME OF ELEMENT				
	6-50 OST 2072 2107 2108 2109 2108 URL 60 OST 2210	SPINDLE PIN LUBRICATION RING DUTTO SETNUT	SETTING SPINDLE TAKE SPINDLE (COMPLEX Y) SET BEARING WITH LUBRI- CATING RING IN BOX CASE TIGHTEN SCREW MM 22 AND SET PIN 8 x 50 PUT ON SPINDLE, ADDING THE FOLLOWING ELEMENTS 19-C, 612109, 612110, 612108, URL 60, OST 2210, 612022, MM 20, AND FASTEN REGULATE SPINDLE IN RADIAL DIRECTION WITH NUT OF BEARING IN AXIAL DIRECTION WITH SETNUT	LEAD HAMMER HAMMER Screwdriver Screwdriver IMD 11, SPECI- AL DRIFT - 2 PIECES WRENCH 80-95/OST 4148 SETNUT	I-IV	
	612028 612029 612174 20-CP-10 MM 20 OST 2081 OST 207 MM 10 OST 2081 612177 125 OST 2105 OST 150	THrust SHAFT RIGHT HAND LEFT HAND SECTOR SLIDE BLOCK RING SCREW PIN SCREW PIN BUSH SPLINT	SETTING SHAFT OF GEAR SHIFT TAKE LEVERS 612029 612030 FROM SWITCH SHAFT (GROUPS 21, 22) PUT SHAFT IN BODY ADDING THE FOLLOWING ELEMENTS 612027, 612031, LEVERS 21, 2028, 612030 AND RING 20-59-10 PUT ON PIN OF LEVER OF SLIDE BLOCK 612174 AND PUT SWITCH SLEEVE IN GROOVE	LEAD HAMMER DRIFT HAMMER 80-95/OST 4859	I-IV	

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Moving assembly is characterized in that the product, in the process of its displacement from one working place (station) to the other, at which a worker or group of workers is constantly present, is given one and the same repeated treatment; during this process, each of the working places, at which the corresponding tools and accessories are present, is supplied with the elements and assembly units necessary for the given operation.

The mentioned forms of organization of the assembly work are used at various forms of production: the stationary form in individual and series production, and, for individual assembly units, in mass production; the moving form in series and mass production.

The execution of the process of total assembly at these forms of organization of the work may take place according to various methods.

The first method of assembly consists in that the machine is completely assembled from individual elements by the same team of assemblers from beginning to end. This method, employed at stationary assembly, is characteristic of and inherent in individual (unit) production, so that it is sometimes called the individual method. This is an obsolescent method of assembly. In the assembly of the whole machine the elements must be matched for size at the place of their joining with other elements, because in individual production the elements are not interchangeable.

The time expended on the assembly of the whole machine is usually long, which is due to the particularities of this method: the plan of the assembly is formulated schematically or is sometimes formulated by the assemblers themselves; the adjustment and fitting of the elements introduces uncertainty into the establishment of the times necessary for the assembly.

The cost of the assembly is considerable as a result of the use of this method. This is the reason why this method is, whenever the character of the production makes it possible, replaced with another method giving a better technico-economic

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effect.

The second method of assembly consists of the assembling of the machine by the same team of workers from individual elements and assembly units preliminarily assembled by other workers outside of the stand of the total assembly and not entering into the composition of the team carrying out the total assembly of the machine. Therefore, a partial differentiation of the assembly process takes place. This method is more productive, because the elements are preliminarily assembled to units, thanks to the fact that the stay of the machine at the general-assembly stand is shorter. Specialization of the work of assembly of units can be carried out, thereby shortening the time for these manipulations; moreover, the qualifications of the workers can be better utilized for the assembly of both the units and the whole machine. This method is used in stationary assembly in series production.

The third method consists of the process of assembly and is subdivided into individual operations, each of which is carried out at one particular working place (moving or stationary) by a particular worker or group of workers in the same (as nearly as possible) interval of time, with observance of a particular assembly heat. This method is employed in mass and series (particularly large-series) production, when the assembly takes place according to the flow principle.

A. Unit Assembly of Machines

Hand treatment of the elements, widely used at individual and small-series production, is carried out at workbenches, to which vises are fastened.

The workbenches must have drawers for keeping the tools or trays with a nest for each of the tools. The tools must be kept sorted according to type, and each type must have its own place. This system eliminates waste of time in finding tools.

At precise and fine work, at which the mechanic works seated, the whole space below the top of the workbench should not be occupied by drawers; room must be left for the legs of the worker. The workbench must be strong enough not to shake or

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move during the work. On the workbench the vises are placed in a row at such a clearance from each other that the workers do not crowd each other. The area of the workbench allotted to each working place must be sufficient for keeping the tools, drawings, materials, elements, and, of course, be carrying out the expected treatment; therefore the center to center clearance between the vises must be at least 1250-1500 mm, at which the smaller dimension applies to work with small elements. The length of the workbench depends on the areas allotted to the working places; extremely-long multiplace workbenches are inconvenient, because the rough and heavy work carried out on some of the vises, due to shaking, interferes with the more precise work on the other vises.

A two-sided, four-place workbench is very convenient, with two vises on each side; such a workbench is equipped with a wire-netting partition separating the one side from the other.

A single workbench is convenient for precise work, which, for greater stability, is made with a metal-covered wooden top.

The dimensions of the mechanics workbenches are: width, one-sided 750-800 mm, two-sided 1300-1400 mm; height 850-900 mm.

The assembly of bundles and aggregates (mechanisms) may be stationary or moving depending on the size of the production program, the character and overall dimensions of the assembled combinations.

Stationary assembly may be carried out on ordinary mechanics workbenches, on tables and special arrangements; moving assembly may be carried out on rollways, conveyors, special transport arrangements.

Around the workbenches and tables for hand treatment of elements and assembly units, several drilling machines (preferably radial-drilling) must be provided for drilling holes and cutting threads carried out at the assembly, and also presses for rigid connection of elements.

The number of working places for stationary assembly of units and aggregates

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is determined according to formula (175) below for determining the number of stands at general stationary assembly of machines according to the individual and the partially-differentiated methods.

All of the calculations relating to both moving and stationary flow assembly of units and aggregates are carried out analogously to the calculation of the general assembly of whole machines taking place according to the same method.

B. General Assembly of Machines

The general assembly of machines, as stated above, may be organized according to either the stationary or the moving principle of operation depending on the form of the production, the size of the production program, the character of the construction and the dimensions of the machine to be assembled. The stationary form of the organization of the work may be employed in the individual, the partially-differentiated and the differentiated (flow) method of assembly. The moving form of work organization is used only at the differentiated (flow) method of assembly.

Stationary Assembly

The stationary assembly of machines may be carried out depending on the character of their construction: (a) directly on the floor (nonequipped areas); (b) on equipped stands; (c) on bases; (d) on parallels; (e) on assembly machines.

Two types of machines for the assembly of light engines are shown in Figures 96 and 97; one of them (Fig.97) gives the possibility of turning the engine at the assembly for giving it various positions.

The productive capacity of the stand M_{st} , i.e., the number of machines assembled per year per stand at stationary assembly according to the individual and the partially-differentiated method is determined by the formula

$$M_{st} = \frac{F k_{st} t}{T_s} = \frac{F_{d.st} t}{T_s}, \quad (174)$$

where F is the yearly fund of stand time for one shift in hours;

k_{st} is a coefficient taking into account the idleness of the stand for major

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reconditioning;

t is the number of working shifts in 24 hours;

T_s is the standard time for the general assembly of the machine in hours;

$F_{s, st}$ is the actual yearly fund of stand time per shift in hours.

The number of stands necessary for stationary assembly of the yearly number of machines according to the individual and the partially-differentiated method is determined by the formula

$$C_{sb} = \frac{M_{pr}}{M_{st}} = \frac{M_{pr} T_s}{F_{s, st} t} = \frac{M_{pr} T_s}{F_{s, st} t} \quad (175)$$

where S_{sb} is the necessary number of assembly stands;

M_{pr} is the number of machine on the yearly program

The actual yearly fund of the working place (stand is calculated depending on the working conditions used in the shop. The assembly shop is usually planned on

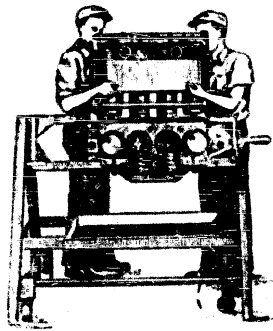


Fig.96 - Machine for Assembly of Engines

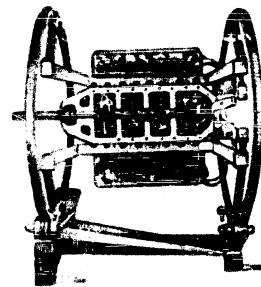


Fig.97 - Machine for Assembly of Engines Enabling Turning of Engine During Assembly

the basis of two, rarely of three, shifts (first and second shifts of 8 hours, third of 7 hours).

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For the equipment of the stand of stationary assembly the time for major reconditioning must be taken into account - approximately 3% of the nominal time fund (coefficient $k_{st} = 0.97$): the actual yearly time fund of the stand is $F_{k, st} = F_{k, st} \cdot$

For nonequipped stands (areas) the actual yearly time fund equals the nominal yearly time fund (for time funds compare Table 19).

Table 19
Time Funds for Stationary Assembly

a	b	c		f	g
		d	e		
1	8	307	2456	2456	2380
2	8	307	4912	4912	4760
3	8	307	7061	7061	6850

* 8 for first and second shifts, 7 for third shift.

a) Number of Shifts; b) Number of Working Hours per Shift; c) Nominal Time Fund; d) in Days; e) in Hours; f) Actual Time Fund for Nonequipped Stands in Hours; g) Actual Time Fund Equals 0.97 of Hours for Equipped

Stand

The stationary form of work organization at the differentiated method of assembly, i.e., flow assembly, is adopted for products of great weight, and hence difficultly transportable (compare below "Stationary Flow Assembly").

Flow Assembly

Flow assembly is defined as an assembly in which the work proceeds uninterrupted and assembled finished products come out periodically at particular intervals of time. Flow assembly may take place with either movement or nonmovement of the object being assembled depending on whether or not the product is displaced in the

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process of assembly.

Flow assembly is divided into two forms:

- (1) Flow assembly on a moving stand (or with movement of the object);
- (2) Flow assembly on a stationary stand (or with nonmovement of the object).

Flow assembly may take place in both mass and series production, and also in small-series production of large products of great weight.

Flow work in the mechanical shop with a change in the type of product requires a complete reformulation of the technological process and replanning of the equipment. At a change in the type of product, however, the assembly flow need not be replanned. The existing equipment is adapted to the new type of product, and a change from one product to another does not create difficulties for the assembly process.

For realizing assembly according to the flow principle the following conditions must be fulfilled:

- (1) Assurance of interchangeability of elements, eliminating fitting of elements into place.

- (2) Division of the whole assembly process into individual operations, with execution times as nearly alike as possible.

Consequently, the times for all of the operations must be in agreement with each other (synchronized), i.e., the times for the individual operations must be equal (approximately) or repetitive. This condition creates a particular beat, giving continuity to the flow of products being assembled.

- (3) The number of workers with indication of qualifications corresponding to the character of the operations must be determined for each of the operations.

Further, the accessories and tools necessary for assuring the working place must be indicated.

- (4) Assurance of regular and timely supply of elements to assembly shop.

- (5) For elimination of delays in assembly, supplies of elements and assembly

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units must be supplied to the assembly place before the beginning of the respective operation.

(6) The planning of the work in the shop must be precise.

The complexity of the adjustments of flow assembly is further compensated by its advantages, as follows: The work is specialized into the execution of particular operations; the time for the execution of each of the operations is considerably shorter because of the specialization of the work; the assembly cost is cheaper, so that the production cost of the product is correspondingly lower; the productive capacity of the assembly shop is considerably increased; the output of products is more regular; the qualifications of the workers are better utilized, because they are distributed according to operations of corresponding complexity; a considerably smaller shop area is required.

Moving-Flow Assembly

Flow assembly on a moving stand, or, as it is often called, flow assembly with movement of the object, is carried out on transport means of various forms:

- (a) On rollways;
 - (b) On trackless trucks, displaced by hand;
 - (c) On track trucks, displaced by hand;
 - (d) On track trucks, coupled together and forming a truck conveyor, driven by an electric motor;
 - (e) On belt, apron and suspended endless conveyors;
 - (f) On special assembly conveyors suitable for the assembly of the particular product;
 - (g) On tracks on which the machine (for example, car or locomotive) is displaced on its own wheels or on wheels temporarily mounted thereon;
 - (h) On suspended monorails;
 - (i) On rotating tables.
- Flow assembly, at which the product is present on a moving stand, is carried

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out as follows. The assembly process is divided into the simplest operations, requiring small and approximately equal time intervals for their execution; for each of the operations a particular working place is provided and a particular worker (or group of workers) carrying out only one simple operation. The product present on the moving stand is displaced; the worker (or group of workers) carries out his (its) operation when the product arrives at his (its) working place. The advance of the product may be continuous or periodical - interrupted from station to station. In the first case, i.e., at continuous advance of the product, the worker carries out his operation during the movement of the conveyor while the product is traversing the zone of the working place; and the speed of movement of the conveyor must correspond to the time necessary for the worker to carry out his operation, which means that the working beat is determined by the speed of movement of the conveyor.

In the second case, i.e., at periodical advance of the product, the worker carries out his operation while the conveyor is standing still; the duration of the stop corresponds to the time necessary for carrying out the operation at each working place; this determines the beat of the conveyor.

Moving conveyors (continuous or periodical) are used depending on the size of the production program, the rate of output, the character of the assembled product, the labor requirement and complexity of the assembly operation, and other technological factors.

Preliminary combining of elements into bunches, mechanisms, aggregates, which are mounted on the machine in finished form are used in flow assembly, for simplifying and accelerating the execution of the assembly operations.

A scheme of flow assembly with movement of the object is represented in Fig.98.

At the flow method of assembly the formulation of the technological process of the assembly work plays a particularly important role; the plan of the assembly must be formulated minutely, clearly and precisely, because the smallest delay at any

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stage of the work leads to disturbance of the whole process. The work must be distributed over all of the working place with such a precision that the assembly process proceeds uniformly at the established beat. Provisions must be made for assuring timely supply to the working places before the beginning of the operations of all of the elements, units, appurtenances, accessories, tools and materials necessary for the assembly of the machines.

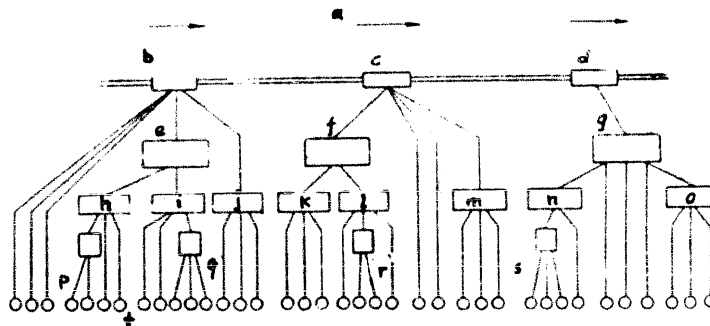


Fig. 98 - Scheme of Flow Assembly with Moving Object

a) Main line of assembly stream; b) Machine, 1st operation; c) Machine, 2nd operation; d) Machine, 3rd operation; e-g) Aggregates; h-o) Bundles; p-s) Sub-bundles; t) Elements

As already stated, the assembly process must be divided into the simplest operations with approximately the same execution times. However, it sometimes happens that operations because of their character, cannot be divided into individual parts because of their connections with one another; the time for the execution of this operation will not be the same as time for the remaining operations. In this case, for obtaining synchronization of the assembly operations, i.e., bringing the operational times into correspondence with the assembly beat, various technological and organizational measures, of which the following may be mentioned are possible:

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(1) Increasing the number of works for the given operation of the character of the operation permits it;

(2) Employment of special accessories and tools;

(3) Preliminary combining of elements to assembly units;

(4) Combining (enlarging) or dividing (diminishing) operations;

(5) Organization of parallel working places on line of assembly flow.

By the use of different numbers of workers on the individual operations of the assembly process (for the determination of the number of workers per operation compare section 33 of this chapter) it is possible to obtain execution of the operations in time intervals corresponding to the assembly beat, provided, of course, the technological character of the operation enables it to be carried out by several workers simultaneously. In this case, the average number of workers assignable to one working place is determined by the average "density" of the work, which is one of the technico-economic indices of the work of a conveyor.

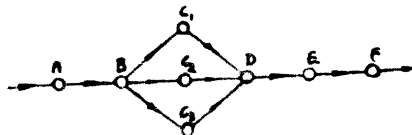


Fig.99 - Scheme of Flow Assembly with Parallel Working Places

The number of working places at which the same operation is carried out in parallel in the flow line is determined by the following formula

$$r = \frac{t_0}{t_v} \quad (176)$$

where r is the number of parallel working places;

t_0 is the time of the operation longer than the flow beat in minutes;

t_v is the output beat in minutes.

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Thus, for example, if for the execution of the first operation at working place A there is required 5 minutes second operation at working place B there is required 5 minutes third operation at working place C there is required 15 minutes fourth operation at working place D there is required 5 minutes fifth operation at working place E there is required 5 minutes etc., then, for execution of the third operation, in order not to spoil the flow beat, it is necessary to provide three working places, at which the work will be carried out in parallel. In Fig. 99, the scheme of the flow for such a case is represented; for the third operation of assembly the product is detained at the working places C_1, C_2, C_3 for 15 minutes, arriving at them in turn every 5 minutes; first one product from the place B arrives at the place C_1 , after 5 minutes the second product at the place C_2 , after another 5 minutes the third product at the place C_3 ; in the next 5 minutes at the place C_1 the operation is finished, lasting 15 minutes, the product goes to the place D, and instead of it a new product arrives at the place C_1 . The process at the places C_2 and C_3 also proceeds in the same order. A product issues from these places every 5 minutes, so that the beat of the whole flow is the same.

The output beat of products, i.e., the time interval at which assembled products issue from the flow line, is determined on the bases of the yearly output of products (or daily or hourly output) by the formula

$$t_v = \frac{60 F k_p k_t}{M} \quad (177)$$

or

$$t_v = \frac{60 F k_p k_t}{M}, \quad (178)$$

where

$$F_{\delta.p} F_{k_p} k_t;$$

F is the yearly number of working hours for conveyor assembly at one shift (nominal yearly time fund);

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$F_{d.p}$ is the actual yearly number of working hours for conveyor assembly at one shift (actual yearly time fund);

t is the number of shifts;

M is the yearly output of products in pieces;

k_r is a coefficient taking into account the idleness of the conveyor equipment for major reconditioning ($k_r = 0.96$);

k_p is a coefficient taking into account work interruptions simultaneously on the whole flow line for servicing the working places, physical demands and relaxation.

In machine-building production usually $k_p = 1$, i.e., simultaneous stoppage of work on the whole flow line does not take place, and workers are substituted if necessary. Otherwise, it is assumed that $k_p = 0.95$.

If the calculation of the output beat is based on the hourly output of products, the value of the beat is expressed as follows:

$$t_v = \frac{60}{H} \quad (179)$$

where H is the hourly output of products in pieces:

$$H = \frac{M}{F_{d.p} k_r t} = \frac{M}{F_{d.p} t} \quad (180)$$

The actual yearly time fund for conveyor assembly is determined according to the nominal time fund taking into account the idleness for major reconditioning (approximately 4% of the nominal time fund; coefficient $k_r = 0.96$).

The time funds for conveyor assembly are listed in Table 20.

At larger production programs the output of products may show that each of the assembly operations requires for its execution more time than the value of product-output beat.

In this case the assembly takes place on several flow lines, from which the products issue in turns.

The number of flow lines necessary for assuring the total yearly output of pro-

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ducts according to the given production program is determined by the formula (181)

$$P = \frac{t_r}{t_v}$$

where P is the number of flow lines;

t_r is the working beat of each of the flow lines in minutes;

t_v is the beat of the total output of products according to the given yearly production program in minutes.

Table 20
Time Funds for Conveyor Assembly

a	b		c	
	e	d	f	g
1	307	2456	2360	2370 ($k_r = 0.965$)
2	307	4912	4720	4690 ($k_r = 0.955$)
3	307	7061	6780	6635 ($k_r = 0.940$)

a) Number of Shifts; b) Nominal Time Fund; c) in Days; d) in Hours;
e) Actual Time Fund in Hours; f) At $k_r = 0.96$; g) According to Data
of Some Projected Organizations

From Formula (181) it is seen that the working beat of each individual flow line is

$$t_r = t_v P. \quad (182)$$

As already stated, the assembly may take place at continuous advance of the products (i.e., during the movement of the conveyor with the products) or at periodical advance of the products (i.e., while the conveyor is standing still).

If the assembly takes place at continuous advance of the products, the product-output beat of one flow line equals the working beat corresponding (approximately or exactly) to the time of execution of the operations at the working places, that is:

$$t_v = t_r \quad (183)$$

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If the assembly takes place at periodical advance of the products from station to station the output beat t' equals the working beat t'_r plus the time for the displacement of the products t_p from station to station (from one working place to the other), that is:

$$t'_v = t'_r + t'_p \quad (184)$$

The velocity of movement of the conveyor at continuous movement thereof is

$$v = \frac{l}{t_v} = \frac{l}{t_r} \text{ m/min} \quad (185)$$

and at periodical movement of the conveyor

$$v' = \frac{l}{t_p} \text{ min} \quad (186)$$

where l and l_p are the center to center clearances between two machines being assembled (or between two working places or stations).

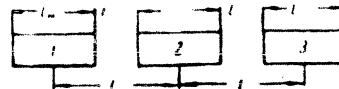


Fig.100 - Determination of Center to Center Clearance between Two Assembly Places (Stations)

l is the center to center clearance between two assembly places (stations);

l_m is the length of the machine being assembled; 1-3 are machines being assembled

The working length of the flow assembly line (conveyor) equals the number of assembly places (stations) multiplied by the center to clearance between two assembly places:

$$L = l n \quad (187)$$

where n is the number of assembly places (stations), equals the number of assembly places.

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The center to center clearance l between two assembly places (stations) is determined on the basis of the length of the machine to be assembled l_m and the interval between two machines to be assembled l_{pr} (Fig. 100) is assumed as dependent on their dimensions (0.3-1.0 meter):

$$l = \frac{l_m}{2} + l_{pr} + \frac{l_m}{2}. \quad (188)$$

From this it follows that the length of each station of the assembly line is

$$l = l_m + l_{pr} \quad (189)$$

The number of assembly places (stations) may be determined on the basis of the beat of output of products (machines, assembly-units); it is

$$i = \frac{T_{sb} 60}{t_v R_{sb.sr}} \quad (190)$$

or substituting the value of t_v from Formula (178), we get

$$i = \frac{T M}{F S_p t R_{sb.sr}}. \quad (191)$$

where T is the total time for assembling the machine (or assembly unit) in hours;

$R_{sb.sr}$ is the average number of workers present at one working place, i.e., the average working density.

The total time for executing the assembly T at continuous movement of the conveyor is

$$T_{sb} = i t_v = i t_p \quad (192)$$

If the assembly occurs at periodical movement of the conveyor, then the total time of the productive process T'_{sb} is composed of the time expended directly on the assembly and the time for displacement of the product:

$$T'_{sb} = i t_p + t_p (i - 1); \quad (193)$$

$$T'_{sb} = T_{sb} + t_p (i - 1). \quad (194)$$

As follows from what has been stated, the fundamental starting magnitude for calculating flow assembly is the working beat, which is determined depending on the character of and the labor expenditure on the operations carried out at each of the working places.

The degree of utilization of the time directly on the assembly is characterized

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by the coefficient of utilization of the assembly time of the flow, which equals the ratio of the time expended directly on the assembly operation to the total time the product is present in the assembly process. This coefficient may be expressed by the following formula:

$$k_{sb} = \frac{T_{sb}}{T_{sb} + T_{tr} + T_{o.sb} + T_{o.dr}} \quad (195)$$

where k_{sb} is the coefficient of utilization of the assembly time of the flow;

T_{sb} is the time expended directly on the assembly operation;

T_{tr} is the time for transportation in the assembly process;

$T_{o.sb}$ is the time of the delay of the assembly due to incomplete agreement between the beat of the preliminary assembly of unit and the beat of the general assembly;

$T_{o.dr}$ is the time of the delay of the assembly due to incomplete agreement with the working beats of the other shops.

In the planning it should be assumed that $T_{o.sb} = 0$ and $T_{o.dr} = 0$, i.e., there must be no delay of the conveyor.

The delays of the conveyor (if such are actually present) for the purpose of eliminating their causes must be taken into account for the determination of the actual value of the coefficient of the actual assembly process (i.e., for ascertaining the actual utilization of the assembly time under the given real conditions). The closer the coefficient k_{sb} is to unity, the better is the organization of the flow process, and the greater is the degree of utilization of the time on useful work, i.e., directly on execution of the assembly operation.

At continuous movement of the conveyor $T_{tr} = 0$ and $T_{o.sb}$ and $T_{o.dr} = 0$ also (i.e., there must be no delay whatever of the conveyor, which means that $k_{sb} = 1$. If at periodical movement of the conveyor $T_{o.sb}$ and $T_{o.tr} = 0$, then the value of k is close to unity. An acceptable value of this coefficient may be regarded as 0.95.

The velocity of movement of the conveyors at the assembly will vary depending on the size of the production program, the product-output beat, the character and

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conditions of execution of the assembly operations, the construction of the conveyor and other productive factors. Thus, for example, the velocity of movement of a main conveyor for the general assembly of motortrucks (loading capacity 3-4 ton) is 0.5-2.2 mm at an assembly beat of 6.5 min; the velocity of movement of the conveyor for the assembly of the same engines of the same automotive vehicle is 0.33-13.0 mm at an assembly beat of 4 min.

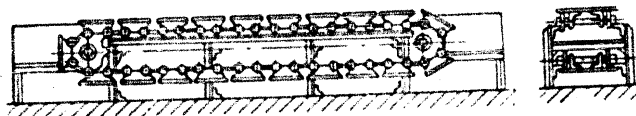


Fig. 101 - Floor Truck Vertically Closed Conveyor

The velocity of movement of continuously-moving assembly conveyors goes up to 5 mm.

Conveyors for assembly work are employed in various constructions, depending

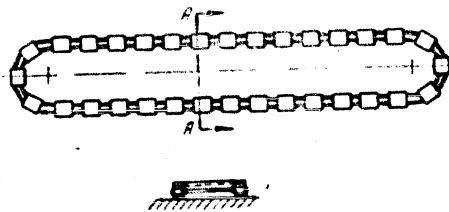


Fig. 102 - Floor Truck Horizontally-Closed Conveyor

a) Section along AA

on the character of the product to be assembled: floor trucks-vertically-closed (Fig. 101) and horizontally-closed (Fig. 102); conveyors, apron, belt conveyors (Fig. 103).

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In autobuilding for the assembly of aggregates (engines, gear boxes, rear axles, reducing gears, control mechanisms, etc.) coupled truck vertically-closed conveyors are used. For general assembly of automobiles vertically-closed and partially-apron coupled conveyors are used.

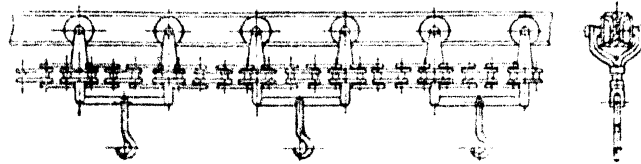


Fig.103 - Suspended Conveyor

In machine-tool building, motor building and other branches of machine building, flow-assembly is often carried out on trucks coupled together and moving on rails thus forming a truck conveyor.

For flow moving assembly, rollways, suspended one- and two-rail lines are used besides conveyors, on which the products being assembled (cars, locomotives) are displaced on their own wheels.

By the use of the one or the other transport means, a straight or an annular flow line can be obtained, for example, with truck vertically-closed conveyors the line is straight and with truck horizontally-closed conveyors it is annular.

In assembly with trucks displaced on rails the flow line may be straight and annular.

With straight flow lines the track truck is returned to the original station empty. Its displacement from the last to the first flow station is done by various methods:

- (1) By means of the bridge crane serving the assembly shop;
- (2) By means of a second parallel truck, on which the truck passes through

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turntables (Fig.104a);

(3) By means of an inclined track in a tunnel, where the truck is let in at the one end and taken out at the other end by a bridge or rotating crane (Fig.104b).

The first method is the simplest, and is the most frequently used when a bridge crane is available; the second method is less convenient because it requires a considerable area, and, a rotating crane is involved besides, which complicates and de-

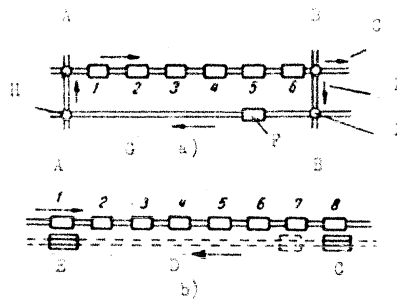


Fig.104 - Scheme of Return of Truck with Straight Flow Line

- (a)- A) Beginning of flow; B) End of flow; C) Direction of machine being assembled; D) Direction of empty truck; E) Turntable; F) Empty truck;
 C) Track for return trip of truck;
- (b)- A) Beginning of flow; B) End of flow; C) Opening; D) Inclined track for return trip of truck; E) Opening

lays the transfer; the third method has the advantage that it does not occupy any of the shop area, and that the truck moves by gravity on the ramp.

With an annular flow line (Fig.105) the truck after completion of the last operation, i.e., after the last station, goes directly to the first station, so that the truck does not have an empty return trip.

For the assembly of small products (apparatuses), small assembly units and aggregates, if the number of assemblers is small, it is convenient to use a rotating

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table (Fig.106) around which the workers carrying out the successive operations are placed. At the rotation of the table the product being assembled is transferred from the one working place to the next. The table may have continuous or periodical

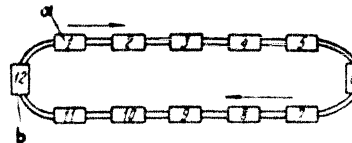


Fig.105 - Scheme of Annular Flow Line

a) Beginning of flow; b) End of flow

rotation. At continuous rotation of the table its velocity must correspond to the times necessary for carrying out the operations at each of the working places. At

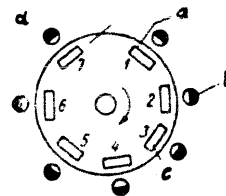


Fig.106 - Scheme of Assembly on Rotating Table

The numbers denote the serial numbers of the operations.

a) Beginning of assembly; b) Working place; c) Product;
d) End of assembly

periodical rotation of the table the operations at the working places are carried out

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in the resting periods of the table. For flow assembly on rotating tables much less area is necessary than for assembly on the usual tables.

Stationary Flow Assembly

Flow assembly at stationary stands, or, in other words, with nonmovement of the object, proceeds as follows. The whole assembly process is divided into operations taking approximately the same time carried out by particular groups of workers, each of which goes from one stand to the other carrying out on the assembly of the machine only its own operation at fixed time intervals corresponding to the assembly beat of the machine.

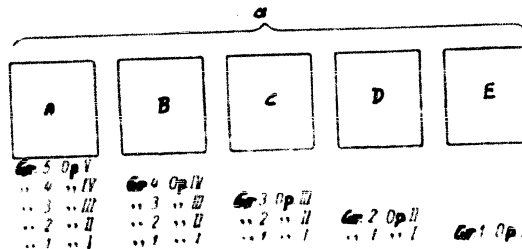


Fig.107 - Scheme of Flow Assembly at Stationary Stands

a) Stands; b) Gr means group; Op means operation

The fundamental machine, frame, plate, body or other object is placed on the stationary stands in the sequence of the assembly operations. Each group of workers, in carrying out its specific operation, moves from the first stand to the second, then to the third, etc. Accordingly, the groups of workers move by stands from one machine to the other. With this working method the tools of each group of workers are present on a moving table, which is displaced together with the workers from one stand to the other. In Fig.107 assembly stands, A,B,C,D,E, are represented in which operations I,II,III,IV,V are carried out. The first group of workers carries

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out its operation I at stand A; then it goes to stand B, and the second group comes to stand A for carrying out operation II. Next the first group goes from stand B to stand C for carrying out its operation I; the second group, having by this time finished its operation at stand A, goes to stand B, and the third group takes its place at stand A for carrying out operation III. In this order the whole assembly process proceeds.

Finished machines are taken in turn from stands A, B, C, D and E at equal time intervals corresponding to the output beat. It should be noted that with this method of assembly a frequent transfer of workers from one stand to the other is disadvantageous. Therefore the assembly process must be divided into operations of comparable work-inputs and durations, at which it is most convenient for the duration of the operations to be equal to or a multiple of the number of hours of the working day. Then the worker begins his operation at the next stand at the beginning of the shift or after the lunch hour. In this case the base (or frame) of the next machine is delivered to the stand during nonworking time (after the end of the shift and during the lunch hour).

At the division of the assembly process into individual operations, the allotment of the operational times in correspondence with the assembly beat takes place with the help of the same technological and organizational measures as already explained for the case of moving flow assembly.

Flow assembly in general, and at stationary stands in particular, requires a precisely-formulated plan, rational division of the whole process into individual operations with equal (insofar as possible) times for their execution, accurate and delivery of the elements and assembly units, and very clear planning and organization of the whole task. It is only at the observance of these conditions that the whole assembly process proceeds smoothly and uniformly; otherwise, at a delay of one group of workers in carrying out its operation the other groups of workers are left without work because they cannot go to the next stand for carrying out their opera-

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tion, so that the continuity of the work is disturbed.

The introduction of flow assembly at stationary stands does not require any expenditure for equipment, but does require considerable reworking of the work and suitable organization. This form of assembly is used for series production, particularly with products of great weight, which are difficult to transport or require complicated transport means. It should be noted that when it is properly organized, this assembly method gives a good technico-economic effect.

From what has been stated it follows that with flow assembly at nonmovement of the product:

(a) The number of stands for carrying out the whole assembly of the machine equals the number of operations into which the whole assembly process is divided;

(b) The number of machines undergoing assembly at the same time equals the number of stands:

(c) The machine-output beat is determined analogously to what has already been explained for flow assembly with movement of the product, i.e., it equals the actual time fund (particular segment of time) divided by the number of machines to be put out in this time;

(d) The total time for the assembly of the whole machine is

$$T = t_i \quad (196)$$

(e) The number of flow lines necessary for assembling the given number of machines on the yearly program is determined by the formula

$$P_{n.p} = \frac{M_{pr}}{M_{st} J}, \quad (197)$$

where $P_{n.p}$ is the number of flow lines for stationary assembly;

M_{pr} is the number of machines assembly per stand per year (productive capacity of the stand);

J is the number of stands equal the number of assembly operations.

The productive capacity of each stand is

$$M_{st} = \frac{F_{d, st} t}{T_{sb}}, \quad (198)$$

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where $F_{d.st}$ is the actual yearly time fund of the stand per shift in hours;

t is the number of working shifts in 24 hours;

T_{sb} is the total time for the assembly of the whole machine.

Substituting the value of M from Formula (198) in Formula (197) we get

$$P_{n.p} = \frac{M_p T_{sb}}{F_{d.st} t} \quad (199)$$

The actual yearly time funds of the stands are taken according to Table 19.

32. Hoist-Transport Equipment

In assembly shops, at execution of the operations, and also for transporting elements, assembly units and aggregates, various types of hoist-transport equipment are widely used. The principal equipments in assembly shops are the following:

Cranes: electric bridge cranes, boom cranes, bracket cranes (portable and stationary), rotating cranes;

Suspended equipment: suspended boom cranes, electric telfers, hydraulic and pneumatic hoists moving on a suspended monorail; suspended conveyors;

Floor equipment: rollways, slideways, chutes, conveyors of various kinds, electric, motor and hand trucks, tractors with trailers, automobiles.

The selection of the types of hoist-transport equipment takes place on the basis of the purpose and its technical characteristics. (On Intraworks Transport compare Chapter XV.)

33. Composition of Personnel and Determination of Numbers Thereof

The personnel of an assembly shop is composed of the following:

- (1) Productive workers;
- (2) Auxiliary workers;
- (3) Younger service personnel;
- (4) Service: engineer-technical and accounting-office personnel.

The total number of productive workers of the assembly shop is composed of the following groups:

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- (a) Mechanics for hand treatment;
- (b) Assemblers for unit assembly;
- (c) Assemblers for general assembly.

The numbers of workers required for the individual stages of the work (hand treatment, assembly of units, general assembly) are determined on the basis of the standard times established for the execution of the various tasks.

The number of mechanics for hand treatment of individual elements is determined by the formula

$$R_{sl} = \frac{\sum t_k D}{60 F_{d,r}}, \quad (200)$$

where R_{sl} is the number of mechanics;

t_k is the piece-calculation time per element in minutes;

D is the number of elements of the same kind treated in a year;

$F_{d,r}$ is the actual yearly fund of working time in hours.

The number of assemblers for stationary assembly of assembly units and whole products is determined by the formula:

$$R_{sb} = \frac{\sum T_k M}{F_{d,r}}, \quad (201)$$

where R_{sb} is the number of assemblers;

T_k is the standard (calculation) time for the total assembly of the assembly unit or the whole machine in hours;

M is the number of assembly units or machines to be assembled in a year.

For obtaining an optimal utilization of the working time at stationary assembly it is necessary, in the calculation of the required numbers of works and the formulation of the assignments of the workers, to seek to occupy the workers time as fully as possible.

The number of workers necessary at each working place for carrying out the assembly operations in the flow line depends on the time necessary for carrying out the given operation and on the working beat.

This number is determined by the formula

$$R_{ib} = \frac{t_{shf}}{t_r}, \quad (202)$$

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where t_{aht} is the time for the execution of the assembly operation in minutes;

t_r is the working beat in minutes (at continuous movement of the conveyor the working beat equals the output beat: $t_r = t_v$).

When the number of assemblers R_{sb} comes out in a fraction it is rounded to a whole number, which is called the taken number of assemblers R_{pr} .

If the rounded value of R_{pr} is 2 or more, and the operation, because of its character, cannot be carried out simultaneously by two or more workers, then, for avoiding disturbance of the working beat, it is divided into several operations, or, if possible, is assigned to parallel working places.

The ratio of the calculated to the taken number of workers is called the coefficient of loading of the working place in the flow line. It determines the utilization of the working time, and is expressed by the formula

$$\eta_r = \frac{R_{\text{sb}}}{R_{\text{pr}}} \quad (202)$$

An acceptable value is $\eta_{r.m}$ is not smaller than 0.95.

The total number of assemblers on the whole flow line is obtained by summation of the taken numbers of assemblers at all of the working places:

$$R_p = \sum R_{pr} \quad (204)$$

In flow assembly it is also necessary that all of the working places be as fully loaded as possible; here, the only permissible losses of working time are those due to small difference between the beat and the actual duration of the working time in various working places of the flow, i.e., the actual working density.

The nominal and actual yearly funds of working time of assembly shops are determined in the same way as for mechanical shops, and are expressed in the same numerical values (compare Chapter III).

The qualifications of the productive workers for shops of series production are determined at approximately 4.0-4.5 class and for shops of mass production at 3.2-3.8 class.

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For carrying out auxiliary work in assembly shops, as also in mechanical shops, auxiliary workers are included into the composition of the working personnel. These include crane-suppliers of tools, storekeepers, transport workers, etc.

The number of workers of each specialty is established on the basis of calculation and practical data depending on the character and volume of the tasks to be performed; the possibility of combining tasks of various professions must be kept in mind.

Detailed calculation of the number of auxiliary workers is usually dispensed with, and instead it is taken in a percentage of the number of productive workers on the basis of practical data. In series production, the number of auxiliary workers of the assembly shop is approximately 20-25% and in mass production 15-20% of the number of productive workers.

The younger service personnel (cleaners of shop and living quarters, messengers, telephonists, etc.) constitutes 2-3% of the total number of workers.

The engineer-technical and the accounting-office personnel constitutes 12-15% of the total number of workers, in which the engineer-technical personnel constitutes 8-10% of the total number of workers, and the rest consists of the accounting-office personnel.

The total numbers of required productive workers, auxiliary workers, younger service personnel and clerical personnel are combined in a general bulletin with indication of the percentual ratios of these categories to the number of productive workers and the total number of workers in the shop (according to the specimen of the bulletin for the composition of the workers in the mechanical shop).

34. Intermediate and Emergency Storages

The intermediate and emergency storages entering into the composition of the auxiliary department of the assembly shop supply the latter with ready elements and assembly units, and thus assure uninterrupted procedure of the assembly work.

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In individual (unit) and small-series production, all of the necessary principal elements must as a rule be presented in stock at the beginning of the assembly, otherwise the beginning of the assembly of the machines may be delayed, uselessly occupying assembly area, which may in its turn necessitate enlargement of the shop area. Because of the necessity of having all of the principal ready elements in stock at the beginning of the assembly, the areas of the storerooms in unit and small-series production are considerable.

In series production, the elements for one series in process of assembly are kept in the intermediate storeroom, so that the size of the storerooms in this form of production may be smaller.

Preliminary assembly, which shortens the length of the stay of the elements in stock, considerably decreases the necessary area of the intermediate storerooms; but in this case space for keeping the elements and assembly units around the assembly place is required. In view of this, storage areas are provided alongside the assembly places, in which elements and assembly units are kept and made up into sets.

Sets of elements and assembly units are sometimes made up in special set storerooms located right in the shop. In this case, the area of the storeroom for keeping the elements and assembly units is considerably smaller.

The supplies of elements, assembly units and aggregates in the intermediate storeroom at the assembly line for assuring uninterrupted working may be taken as follows:

In small-series and series production, according to the size of the lots of machines to be assembled, but not more than 10 days supply; for small elements and assembly units it may be greater - approximately 2 weeks supplies;

In large-series production 5-7 days supplies, including 2-3 days supply for flow lines (large elements and assembly units) - 3-5 days supply for medium-sized elements and 5-10 days supply for small elements.

In flow-mass production, when the beat of delivery of elements from the mechani-

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cal shop is the same as the assembly beat, an intermediate storeroom is unnecessary; however, such an agreement between the beats is difficult to obtain in practice; there is usually a difference between the beats of the mechanical treatment and the assembly. These circumstances, and also the necessity of treating some of the elements in the mechanical shop in lots, make it necessary to have intermediate storerooms at the assembly places for keeping the elements, assembly units and aggregates required at the respective working places.

In the storage of the assembly line, supplies (1-3 days) of products of contiguous productions (apparatuses, standards, etc.) must also be kept, which are procured from the central storeroom of the works.

For keeping these products, shelves, tables, stands and other special means are used. The storage around the assembly places is made in the form of shelves. They are replenished with elements in equal lots at fixed time intervals, making the delivery of the elements and assembly units very simple, and is often expressed in the plan only by the notation of their uniform delivery. The supplies of elements and assembly units at the intermediate storage is taken smaller, usually at 0.5-1 days supply. In the same storages (in the absence of special set storages) elements and assembly units are sometimes made up into the sets required in each of the working places.

The calculation of the area of the storage for keeping the elements and assembly units around the assembly place takes place analogously to the calculation of the intermediate storages explained in Chapter III.

In works of flow-mass production (auto- and tractor-building, agricultural-machine building, etc.) storage-conveyors (suspended, apron, etc.) are often employed to deliver elements and aggregates directly to the assembly places; this eliminates the necessity of intermediate storages, thus decreasing the shop area.

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35. Planning of the Shop and the Working Places

Determination of the Shop Area

The location of the working places for the various forms of work of the assembly shop must correspond to the sequence of the passage of the element through the stages of the assembly. Such a location gives the possibility of obtaining the shortest route for the elements and a constant direction of goods travel.

On this basis the working places in the shop must be located in the following order: (1) hand treatment of elements (if necessary); (2) assembly of units; (3) assembly of aggregates (mechanisms); (4) general assembly of machine; (5) regulation and polishing of machine; (6) testing; (7) packing.

Thus the elements will come from the mechanical shop (via the intermediate storage, or by-passing the latter in the case of large elements) to the respective working places for pre-assembly and general assembly.

On this basis all of the equipment of the working places must be located in the shop in accordance with the sequence of the stages of the assembly process:

Workbenches for hand treatment of the elements (if the character of the production makes this necessary);

Workbenches, tables, rollways, conveyers and special means (depending on the form and method of assembly) for the assembly of units and aggregates (mechanisms);

Nonequipped areas provided with stands, bases, assembly machines, trucks and trackless trucks, rollways, conveyers, tracks, suspended lines (monorails) and machine tools (drilling machines, presses, fastening machines, etc.) for the tasks carried out in the assembly process.

The dimensions of the means and equipments for the assembly depend on the dimensions of the elements to be assembled to units and machines. The dimensions of the workbenches have been reported above.

The location of the workbenches for hand work and unit assembly may be longitudinal or transverse (Fig.108).

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Along the workbenches there must be a passageway; its minimal width is 1500 mm figuring from the boundary line of the working places (Fig.108a). If movement of transport over this passageway is necessary, its width must be taken depending on the transport means used.

In the planning of the assembly places, the following means and equipments must be provided:

(a) Working places for the assemblers with possibility of free passage around

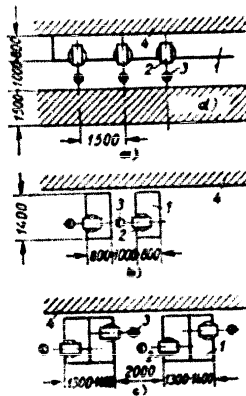


Fig.108 - Scheme of Location of Mechanics Workbenches.

a) Longitudinal; b) Transverse; c) Transverse two-sided workbenches.

1) Workbench; 2) Vise; 3) Working place; 4) Wall. d) Passageway

(b) Places for putting large elements of machines (frames, stands, plates, shafts, etc.);

(c) Places for keeping elements and assembly units (in boxes, on shelves, special tables and stands) in the quantities necessary for assembling the machines present at the assembly stands (the supply of elements and assembly units has been explained above);

(d) Passageways and corridors on the basis of the overall dimensions of the

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transport means for the elements and assembly units.

The widths of the corridors are as follows:

For hand trucks and passage of persons not less than 1.5 meters;

For electric and motor trucks at one-direction movement 2.0-2.5, at two-direction 3.6 meters.

For automobiles at one direction movement 4, at two-direction 6 meters.

In mass-flow production to the working places with an assembly conveyor, the assembly units are fed with a suspended conveyor; here space must be left for the conveyor to unload and load the assembly units.

The areas necessary for carrying out the assembly tasks in the individual states of the assembly, and also for the whole shop, are determined from its plan by preparing the plan of the location of all of the working places, equipments, conveyors or other means, storage places for the elements and assembly units, passageways and corridors, etc. According to the found total productive area of the shop, the specific areas are determined, i.e., the areas for each of the productive workers of the largest shift, which are obtained by dividing the total area of the shop by the number of productive workers working in the large shift.

The specific area gives the possibility of judging the extent to which the area is utilized rationally, and the extent to which the taken area deviates from the normal area assuring the observance of suitable working conditions. Accordingly, the specific area serves as the index of utilization of the productive area. The magnitude of the specific area is different for different branches of machine building, since it depends on the form and method of assembly, the size of the assembly machines, and the length of the assembly cycle.

For series production of machines of medium size (metalworking and woodworking machines, motors, pumps, compressors, textile machines, etc.) the average size of the specific area is 18-25 square meters. Examples of specific areas for various branches of machine building are presented in Table 21.

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If the specific area of only the mechanics workshop (without assembly area) is taken, its value is 5-6 square meters (as can be seen from Fig.108a). In planning according to technico-economic data (at the processing of project data and in other cases) the value of the area of the assembly shop may be determined approximately according to the values of the specific areas.

Table 21

Examples of Specific Areas in Assembly Shops for Various Forms of Machine Building
(Productive Area per Productive Worker in Largest Shift)

Form of Machine Building	Specific Area in Square Meters
Motortrucks (loading capacity 3.5 tons):	
Assembly of motors and gear boxes	18.1
General assembly of vehicle	26.0
Tractor building (caterpillar tractors):	
Assembly of motor	18.7
General assembly of tractor	18.0
Portable-engine building (agricultural)-assembly of fittings and steam engine	25.0
Diesel building (highspeed diesels 5-10 hp)	32.0
Crane building (trucks and driving mechanisms)	35.0
Locomotive building (steam type CO)	60.0

The ratio between the areas of the mechanical shop and the assembly building depends directly on the form of production: For unit and small-series production, the area of the assembly shop is on the average 50-60% of the area of the mechanical shop, in series production 30-40%; in mass production it is 20-30%; in the case of a well-organized assembly line it is only 15-20%.

The width of the aisles of the assembly shops are taken depending on the overall dimensions of the assembly machines, the plan, the overall dimensions of the equipments and working places, the width of the passageways and corridors and other conditions. Most widely adopted are the following widths of the aisles of the assembly shops.

The clearance between columns in the longitudinal direction (pitch of columns)

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is 6 meters, in metal construction 12 meters.

Over-All Dimensions of Products

	Width of Aisle in Meters
Small (apparatuses, typewriters, etc.)	9; 12
Medium-sized (machinetools, motors, automobiles, tractors, etc.)	12; 15; 18
Large (portable engines, cars, locomotives, etc.)	18; 21; 24;
Especially-large (locomotives of great power, heavy machine tools, cranes, metallurgical equipments)	24; 27; 30

The length of the aisle is determined in the same way as for mechanical shops, i.e., by the sum of the lengths of the aisle (along its axis), the successive production and auxiliary departments, the passageways and other parts of the shop. The length of the aisle is a multiple of the dimension of the pitch of the columns.

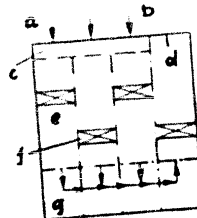


Fig.109 - Scheme of Location of Assembly Shop Parallel with the Aisles of the Mechanical Shop

- a) Entrance of materials and blanks; b) Exit of finished products;
c) Shop storage for materials and blanks; d) Assembly shop; e) Bridge crane; f) Intermediate storage; g)

The assembly shop is usually located in the same building as the mechanical shop, rarely in a separate building. The most rational is the location of both shops in the same building; this reduces the travel of the elements; the feed of the elements to the assembly places is quicker; the transport is simpler and cheaper. Moreover, if these shops are located in the same building the intermediate and other storages as well as the distribution and storage of tools can be combined,

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thus facilitating and accelerating communication between the two shops. In flow production, the treating and assembly lines must, already in the planning stage, be so located that the place of the final mechanical treatment of the element is next to the assembly conveyor, and in a position where this element goes into the assembled unit or aggregate; at such a location of the treating and assembly lines, the element has only a short way to travel to the assembly after treatment.

The location of the assembly shop in relation to the mechanical shop and also the components of all of the production and auxiliary places of the shop must correspond to unflow of the production process.

The location of the assembly shop in the same building as the mechanical shop is carried out as follows:

- (1) The aisle of the assembly shop is located parallel with the aisle of the mechanical shop;
- (2) The aisle of the assembly shop is located in continuation of the aisle of the mechanical shop;
- (3) The aisle of the assembly shop is located perpendicular to the aisle of the mechanical shop.

The first method (Fig.109) is rarely adopted, and then only in the case when the plant site is limited and does not permit locating the assembly shop after the mechanical shop, or when the exit of the finished products can only be on the side of the mechanical and assembly shop buildings where the materials and semiproducts arrive.

In this method of location the transfer of elements from the mechanical to the assembly shop by crane is impossible; the transport of the elements from the mechanical shop is possible only by hand, electric or motor trucks or a suspended monorail line; the feeding of the elements from the aisle of the mechanical shop directly to the assembly stands over the shortest path cannot be realized; the elements, in going from the given aisle of the mechanical shop across the other aisles, must,

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in order to reach the given assembly place, be moved along the assembly shop. In this movement the elements travel a long complicated path.

The second method (Fig.110) is adopted when the products or individual elements to be assembled are brought into the assembly shop by a bridge crane, and when floor transport means are used for bringing the products to the assembly.

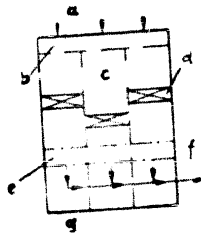


Fig.110 - Scheme of Location of the Assembly Shop in a Continuation of the Aisles of the Mechanical Shop

- a) Entrance of materials and blanks; b) Shop storage for materials and blanks; c) Mechanical shop; d) Bridge crane; e) Intermediate storage; f) Exit of finished products; g) Assembly shop

In this case the elements from the aisles of the mechanical shop to the assembly places present in the same aisles can be fed directly by the bridge crane, but transfer of the products and elements to be assembled into the assembly shop by bridge crane is impossible. This method is often used in small shops, when, because of the small loading of the cranes of the mechanical shop, it would be irrational to provide a special crane in the assembly shop; in large shops it is used when the assembly takes place at moving stands (trucks, rollways, conveyors) and a crane is not needed for transporting the products to be assembled. In this case the width and height of the aisles of them mechanical and assembly shops and also their construction are the same, so that the construction of the building is simplified. At such a location of the assembly shop it is easy to enlarge both shops (mechanical

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and assembly) by lengthening the aisles. Because there is not much equipment in the assembly shop (so that it is easy to move), the relocation of this shop with long aisles, when it is necessary to enlarge both shops, does not present any difficulties. Such a mutual location of the shops is also rational when the production program is unstable and changes in or additions to the list of products may be expected, which requires lengthening of the technological line of the mechanical shop. This can be done by lengthening the aisles, without disturbing the production.

The third method (Fig.111) is used more frequently than either of the preceding ones. This location has a number of advantages. The elements, treated in a particular aisle of the mechanical shop, can be transported to the corresponding place of

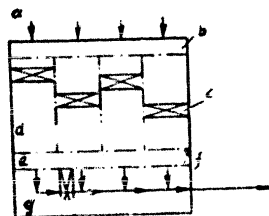


Fig.111 - Scheme of Location of Aisles of Assembly Shop Perpendicular to Aisles of Mechanical Shop

- a) Entrance of materials and blanks; b) Shop storage for materials and blanks; c) Bridge crane; d) Mechanical shop; e) Intermediate storage; f) Exit of finished products; g) Assembly shop

the assembly shop by bridge crane, suspended or truck transported over the shortest path without lost motion along the assembly shop. The products and individual large elements to be assembled can be transported in assembly shop by the bridge crane. At the execution of assembly operations the bridge crane can be used as a hoist at any assembly place, which is important for facilitating the mounting of large ele-

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ments. This assures better utilization of the cranes in the assembly shop.

Besides bridge cranes, floor and suspended transport equipment may also be used

In the transport of elements by bridge crane their transfer from the mechanical aisles may take place by various methods:

1. With the crane of the mechanical aisles the elements are loaded on trucks (track or trackless) or on rollways and transported by them below the crane of the assembly aisles; the elements from the aisles of the mechanical shop can also be transported below the crane of the assembly aisles by means of rotating bridge cranes provided along the columns on the boundary between the mechanical aisles and the assembly shop. This method of transferring the elements is adopted when the cranes of the mechanical and the assembly aisles are present at the same level.

2. With the crane of the mechanical aisles the elements are transported directly below the crane of the assembly shop, for which purpose the crane from the mechanical aisles runs below the assembly (Fig.112). In this case the cranes of the mechanical and the assembly shop are present at different levels, so that the assembly shop must have a greater height than the mechanical shop; the clearance in height between the undercrane rails of the two shops, depending on the over-all dimensions of the cranes, must not be less than 2.75 meters at location of the trolley wires on the side and 3.1 meters at location of the trolley wires on top.

This method of location of the cranes is more convenient in the transport of loads so that the possibility of reloading on trucks is avoided, but it gives a considerable height of the building, and therewith a greater first cost thereof, so that this method is limited to productions with large, heavy elements. This method of location of the cranes in the assembly aisles perpendicular to the aisles of the mechanical shop is often used in works of heavy-machine building.

In Fig.113 there is shown the line of a 10-ton crane from the five aisles of the mechanical shop to the aisle of the assembly shop, served by a bridge crane of loading-capacity 40 tons.

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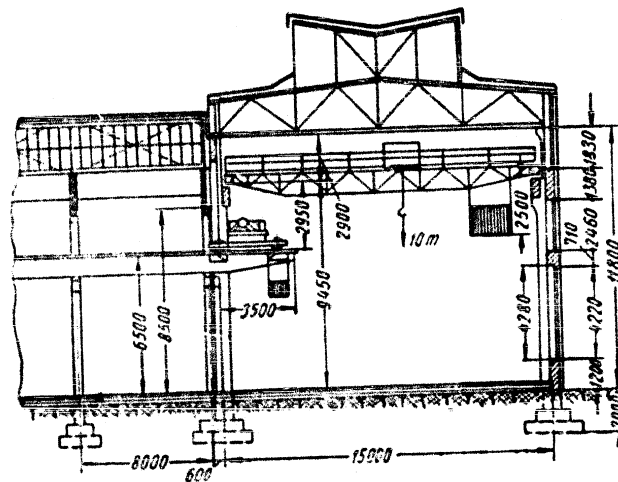


Fig.112 - Scheme of Location of Bridge Crane below Crane of Assembly Shop



Fig.113 - Line of 10-Ton Bridge-Crane from Five Aisles of Mechanical Shop to Aisle of Assembly Shop Served by 40-Ton Crane

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In the assembly shops of heavy-machine building bridge cranes located in two and three tiers (Figs. 114 and 115) are used; in this case the assembly places are served by cranes without delay.

36. Principal Technico-Economic Indices of Assembly Shops

(For further details on the Technico-Economic Indices compare Chapter XXI.)

The cost of executing the planned assembly shop and its economic feasibility are determined by technico-economic indices, which are derived on the basis of technological and technico-economic calculations.

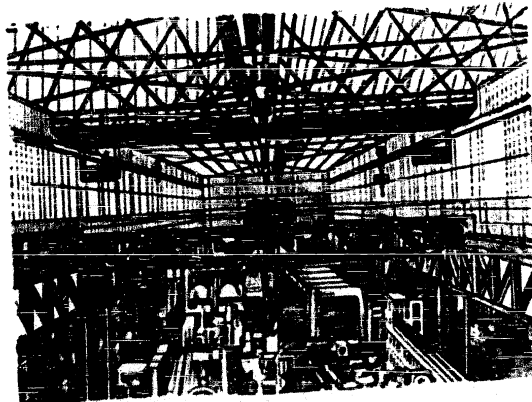


Fig. 114 - Two-Tier Location of Bridge Cranes in Assembly Shop
Loading-capacity of two upper cranes 10 tons each; of lower crane 50 tons

Absolute Indices Characterizing the Productive Capacity of the Shop

1. Yearly output of products in shop cost in rubles.
2. Yearly output of products (complete machines).
3. Yearly output of products in tons.
4. Number of working shifts.

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5. Area of shop in square meters: a) total; b) productive.
6. Number of production equipments (units).
7. Number of workers including: a) productive workers; b) auxiliary workers; c) younger service personnel; d) engineer-technical personnel; e) accounting-office personnel;
8. Fixed assets in rubles, including: a) buildings and structures; b) equipments, tools, accessories; c) production and housekeeping inventories.
9. Yearly budget of productive and other wages.
10. Installed power of electric motors in kilowatts.

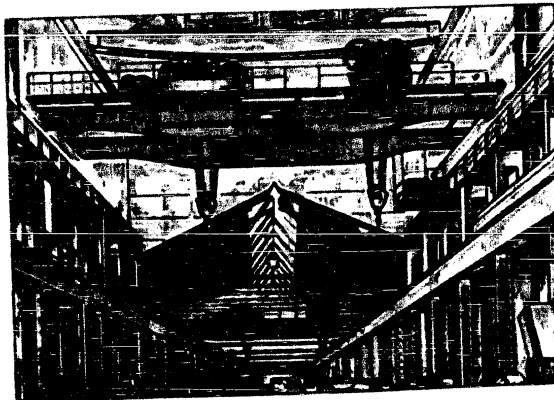


Fig.115 - Three-Tier Location of Bridge Cranes of Loading
Capacity 80 and 100 Tons in 20-Meter Aisle

Relative Indices Characterizing the Technico-Economic Effectiveness of the Shop

11. Yearly output of products in rubles (in production cost); a) per productive workers; b) per square meter productive area per shift.
12. Yearly output of units (machines) in tons per year per productive worker.
13. Yearly output of products (in production cost) per ruble fixed assets.

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14. Yearly output of products (in production cost) per ruble wages of productive workers.
15. Total area of shop per productive worker in largest (according to the number of workers) shift in square meters.
16. Productive area per productive worker in largest shift in square meters.
17. Total area of assembly shop referred to total area of mechanical shop (department) in percent.
18. Coefficient of loading of working places, including coefficient of shifts;
19. Labor-input of assembly of one unit (machine) in man-hours.
20. Labor-input of assembly per ton output in man-hours.
21. Labor-input of assembly referred to labor-input of mechanical treatment in percent.
22. Cost (shop) per product and per ton product in rubles.
23. Shop expenditures referred to productive wages in percent.

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CHAPTER XV

PLANNING OF INTRAWORKS TRANSPORT

99. Means and Forms of Transport

The works transport is divided into three forms: (1) outside; (2) intershop; and (3) shop.

The outside transport serves for connecting the works with the neighboring railroads and highways and with other industrial and commercial establishments. The connecting ways may be highways, wide- and narrow-gauge railroads, waterways.

For transport means on railroads, steam-, gasoline- and electric-locomotives are used, and, on highways, motor trucks and tractors with trailers.

The intershop transport serves for transporting loads between shops. The transport means in this case are electric and motor trucks, motor trucks, tractors with trailers, suspended monorails with electric telfers and wide- and narrow-gauge railroads.

The shop transport serves for transporting loads inside the shop; this form of transport serves the machine tools, assembly stands, working places, shop and storage places. As transport means, the following are used: hand trucks, electric and motor trucks; narrow- and wide-gauge railroads; suspended monorails with electric telfers; rotating cranes in the form of an arm with a tackle or telfer; rotating cranes on columns; bracket cranes; velocipede cranes; overhead booms with a telfer; electric bridge cranes, ordinary and with a rotating arm; conveyors, roll-ways, chutes, slideways, ramps, hoists (lifts); pneumatic hoists.

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100. Selection of Shop Transport

The selection of one or another form of shop transport depends on the following factors: character of product made, its weight and size; form of production

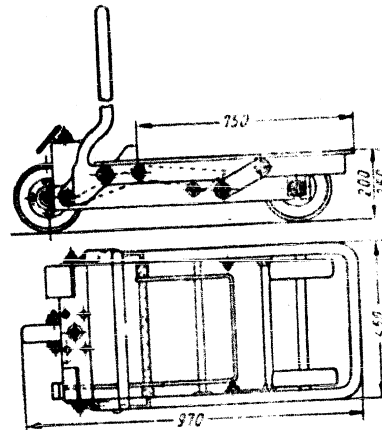


Fig. 145 - Hand Truck with Lifting Platform

and form of organization of work; size of load turnover, i.e., number of loads to be transported; purpose of transport; type and size of building.

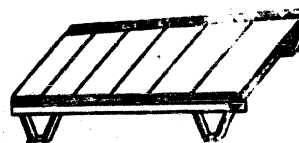


Fig. 146 - Stacking Platform with Legs

In each particular case, on the base of the enumerated factors, and taking into account the conditions of the production, the form of transport which will serve the

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production process the most rationally and economically must be selected. For this purpose it is necessary to calculate the expenditure of time for transporting the given load, to establish in correspondence with this time the beat of the production process, to determine the cost of the contemplated transport, and to ascertain the degree in which it is reflected on the cost of production.

Following are the transport means most widely used in shops and their particularities.

In infrequent transportation of light loads in narrow passageways between machine tools, hand trucks are still sometimes used. The truck with lifting platform (Fig. 1.145), loading-capacity up to 1000 kg, platform dimensions 450 x 750 mm is more convenient.

In the use of trucks with a lifting platform, it is necessary to have boxes with legs or else to place the boxes on special stacking stands with legs (Fig. 1.146) for transporting the loads. In this case the platform of the truck comes underneath the box or stand, and sustains the load; this makes loading and unloading quick and easy.

The most convenient truck transport is the electric truck (Figs. 1.147 and 1.148); they are easy to steer, run without noise, which accounts for their wide use in factories. The electric truck is driven by an electric motor fed by a storage battery. They are built in load capacities of 0.75, 1.0, 1.5, 2, 3 and 5 tons with or without a lifting platform or hoisting crane.

The hoisting crane makes it easy to bring blanks and elements to and take them away from the machine tools. The electric truck is easy to maneuver in the shop, does not require a wide passageway or a larger radius of turning, and because of its rubber tires, runs without noise. For using them in shops it is necessary to have smooth ways (of asphalt, concrete, wooden blocks).

The travel speed of electric trucks is 6-15 km/hr.

The dimensions of the platform of the electric truck, with a loading capacity of

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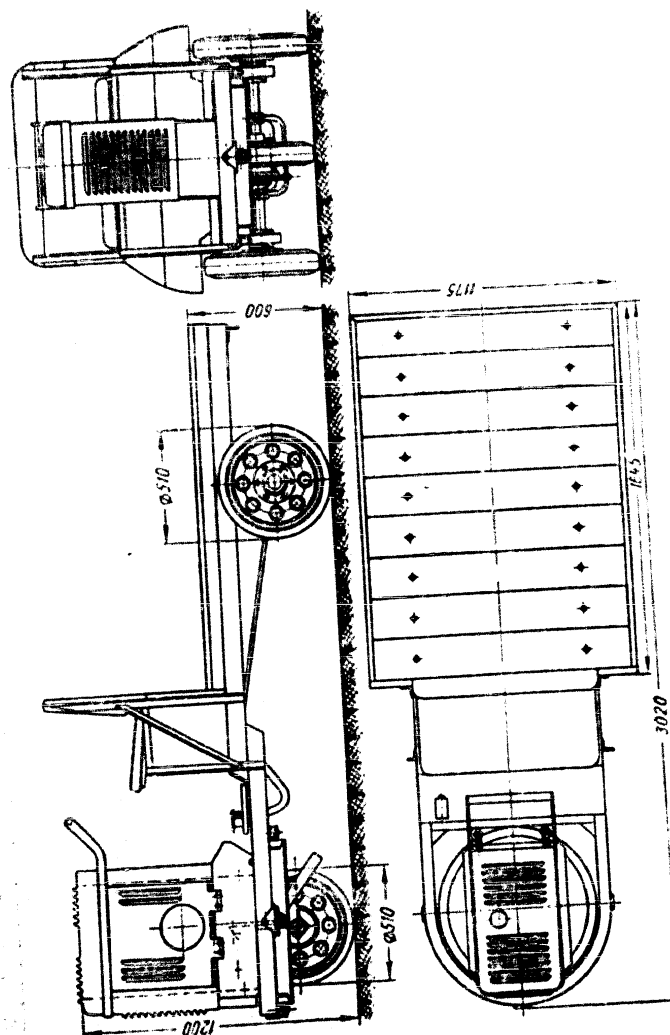


Fig. 11/7 - Electric Truck of Loading Capacity 1.5 Tons

Characteristics: Loading capacity 1.5 tons; rubber-tired wheels sustaining pressure of 750 kg at speed 15 km/hr; brakes on front and rear wheels giving full breakage in 1 m at speed 10 km/hr; first speed 3.5 km/hr; second speed 9.0 km/hr; third speed 15.0 km/hr. $n = 300$ rpm.

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of 1.5 tons, are as follows: width 1000 mm, length 1600 mm; of the electric truck with a loading capacity of 2 tons: width 1150 mm, length 1750 mm; of the electric truck with a loading capacity of 3 or 5 tons: width 1050 mm, length 1850 mm.

Besides electric trucks, motor trucks (autotrucks) driven by a gasoline engine are used.

A disadvantage of the autotruck is the exhaust of the combustion gas and the necessity of using a comparatively expensive fuel, as a result of which it is used much less than the electric truck.

For lifting the loads on automobiles and electric trucks without a lifting platform, automotive lifts (autoloaders) are used.

Narrow-gauge railroad transport is now rarely used in mechanical and assembly shops because it is difficult and sometimes impossible to use it for bringing the elements to the machine tools and assembly stands; moreover, the presence of the

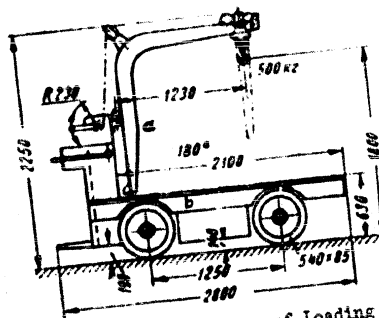


Fig. 148 - Electric Truck with Crane of Loading Capacity 0.5 Ton
a) Angle of rotation 180°; b) Storage battery

tracks (even when "countersunk") and of the turntables represents an inconvenience and spoils the floor. In assembly shops narrow-gauge railroads are used for the movement of the trucks on which the machines being assembled (assembly at moving

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stands) are transported, and also for taking away the finished machines.

Wide-gauge railroad transport is used for bringing large numbers of heavy blanks (castings, forgings) to the shop storages, and also for taking heavy and large finished products away from the assembly shop; in these cases the railroad line runs right into the shop building. Sometimes the railroad line does not enter the shop but runs around it; in this case the finished products are taken out on a suspended line with a telfer or by means of a bridge crane extending out of the shop; the latter method cannot be adopted in regions with severe weather conditions, because the provision of a shutter at the exit of the crane does not assure sufficient protection against the penetration of cold.

Monorails and suspended lines with telferes are used for transporting various materials, semiproducts and products from shop to shop, and of products to and from storages. The use of such lines inside shops is possible for the transport of elements between machine tools, particularly at mass or large-series production when the elements move in continuous flow. For the enumerated cases this form of transport is very convenient, and is widely used.

Monorail suspended lines are hung on the carrying construction of the building or laid thereon at a height of not less than 2.5 meters figuring from the floor to the lower face of the rail.

For monorail lines, I, H or special rolled sections are used.

The monorail line may be straight, annular or in the form of a branching network with branches coming into the range of boom or rotating cranes.

For curved segments the range of curvature is taken at 1 to 5 meters. Individual segments of the line are laid horizontally or with an inclination of 0.5-1.0% in the loaded direction; the height of lift is up to 20 meters. The loading capacity of the telfers is from 0.25 to 5 tons, and sometimes more.

The telfer is controlled from the floor or from a cabin suspended on the telfer; in the first case the travel speed of the telfer is 15-30 m/min and in the

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second up to 100 m/min.

A rotating crane in the form of a simple arm with tackle or telfer or in the form of a crane on a column is used as a local crane serving one particular machine tool or working place (at the most two). Such a rotating crane is used for lifting heavy elements onto the machine tool, and sometimes for transporting elements from a machine tool located in one aisle to a machine tool located in another aisle. The necessity of fastening such an arm or crane on a column of the building must be provided for in advance at the calculation of the columns, because the additional load on the columns sometimes reaches considerable magnitudes.

Bracket electric cranes (Fig. 149) in the form where the bracket moves along the wall on rails are used for serving shop storages or the aisles of large shops. They serve the zone along the wall of the shop; the width of the zone depends on the reach of the bracket. The reach of such a crane is up to 5 meters. On the one hand, these cranes are convenient because they do not occupy any floor area, but, on the other hand, they give a considerable additional load on the wall of the building (tilting moment depending on the reach and loading capacity of the crane), necessitating strengthening the construction of the wall, which, of course, increases the cost of the building. The necessity of installing bracket cranes must be provided for at the calculation of the construction of the building.

The bicycle crane, in contrast to the bracket crane, has one support with the wheels running on the track laid on the floor and a second support with the wheels running on the track laid on top. This type of crane loads the wall of the building considerably less, but, on the other hand, it occupies useful area of the floor on which the track is laid.

The most widely used means of overhead transport in the shop are electric bridge cranes. Their advantages consist in that they constitute at the same time a hoisting and a transporting means, serving the whole area of the shop, at which the width of the aisles reaches more than 40 meters; the hoisting capacity of the

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cranes is up to 350 tons (Fig.150).

Electric cranes are preferably controlled from above (from a suspended cabin); some cranes are controlled from below.

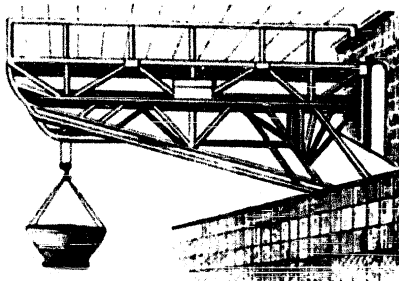


Fig.149 - Bracket Electric Crane

The travel speed of the crane with upper control is up to 125 m/min, while that of those with floor control does not go above 30 m/min.

For transporting elements, products or materials between aisles or for lifting them to the upper gallery of the building, electric bridge cranes with a rotating arm (Fig.151) are used; the length of the arm is 5-8 meters.

In a large number of crane operations, particularly when bridge cranes are used at the execution of technological operations, as, for example, in large assembly and forge shops, the bridge cranes are located in two or three tiers (Figs.114 and 115); with such an arrangement they do not interfere with each others operation.

In storerooms and shops with a small volume of transport, one- and two-boom bridge-cranes are used, the first with a loading capacity of 1-10 tons at a reach of 5-14 meters and the second with a loading capacity of 5-20 tons with a reach of 8-17 meters.

For lifting the loads the one-boom crane is equipped with a hand tackle and

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the two-boom crane with a hand tackle or hand drum winch.

In the shops and storerooms of machine-building works, one-boom bridge cranes with a telfer displaced on the lower part of the crane boom (boom crane) are widely used. The loading capacity of the boom cranes is 0.5-5 tons; the button control may



Fig.150 - Electric Bridge Crane of Loading Capacity 200 Tons

be from above (from the cabin) or from below (from the floor). The travel speed of the bridge boom of such cranes is up to 75 m/min. Often a suspended boom crane traveling on the lower flange of the I beam suspended on the ceiling of the building is used.

Boom cranes have a smaller over-all height (and hence also other dimensions), so that they require a smaller height above the undercrane track and total height of the building. On the dimensions of the cranes connected with the dimensions of the building compare Chapter IVIII.

The principal parameters and over-all dimensions of cranes are given in OST 20195-40, GOST 1441-42, 1442-42, 3332-46.

Conveyors, rollways, inclined planes, chutes, ramps, slideways and similar transport means serve for transporting elements, semiproducts and blanks between working places in the process of production, particularly at flow production.

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Of the various types of conveyors in machine-building production, belt, apron, truck and suspended-chain conveyors are principally used.

The belt conveyor has as its tractive organ a rubberized belt, on which special nests for the elements are sometimes fastened. In mechanical and assembly shops,

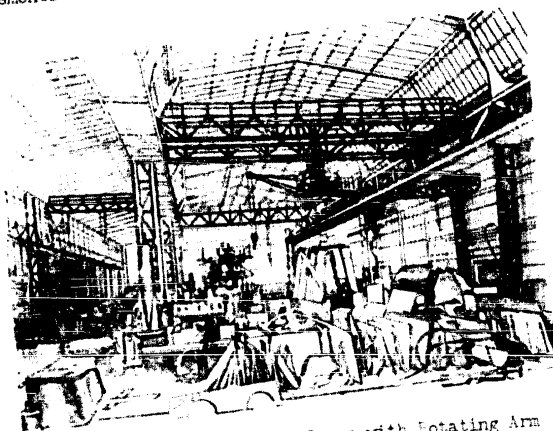


Fig.151 - Electric Bridge Crane with Rotating Arm

conveyors with a belt width of 200-600 mm are used.

The working speed of the conveyors is 6-30 m/min; the transport speed of the conveyors is 30-60 m/min and more.

Apron conveyors have a length up to 200 meters and a width of 400-1600 mm; the most widely used widths are 400, 500, 650 and 800 mm. The working speed of the conveyors is taken at 1-3 m/min, the transport speed at 7-20 m/min.

Truck conveyors, widely used in mechanical assembly, foundry and other shops of flow production, have a continuous or intermittent (periodical, pulsating) movement. They are vertically- or horizontally-closed. The former are used for straight assembly lines, with which the first operation takes place at the beginning and the last operation at the end of the conveyor. The return branch of these conveyors is located below the working branch, above or below the floor; the technological operations can be carried out on both sides of the conveyor. These conveyors have either

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tilting (the most frequently used) or nontilting trucks.

Horizontally-closed truck-conveyors are used for servicing a large number of technological operations, whose location in one straight line would require a considerable length of the shop. Due to the circular movement of these conveyors, the whole length of their running part is utilized.

Such conveyors are widely used in assembly shops directly for the process of general assembly, and also as moving storages feeding elements and assembly units to the working places of the general-assembly line.

The length of truck conveyors for assembly is 15-200 meters at a width of 0.25 of 0.25-3.5 meters.

The speed of the periodical conveyors is 4-5 m/min and that of the continuous conveyors 0.02-4.0 m/min.

The truck conveyors are made according to the dimensions of the products to be assembled, and are equipped with clamps for fastening them.

Suspended chain conveyors consist of a closed tractive means in the form of a chain with suspended carriers for the load, and are widely used in flow production for transporting the elements between the working places and in other shops. With these conveyors the movement of the carriers takes place along rigid guides, which are suspended on the girders, walls or columns of the building. Due to the possibility of formulating spatial routes with turning, raising and lowering of the suspended conveyor, it can pass above the machine tools and working places, and go around corridors and passageways, which enables it to be connected with the transports of the production sections and shops located in different parts and stories of the building and also in different buildings. The conveyor can be inclined upwardly or downwardly up to 45° , and given a radius of curvature of 1.0-1.5 meters. The pulling speed of the chain conveyors is 0.1-25 m/min (usually 3-10 m/min). The center to center clearance between the hangers is taken at 1.0-2.5 meters. For rail lines at a spacing of the pulling chains of 80 and 100 mm, I beams No.12 and 14 are

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taken, and, at a spacing of the

Suspended conveyors are particularly
tors and agricultural machines.

Roller conveyors (rollways, roller tables) are power- or nonpower-driven. With power-driven rollways the rollers are driven from the drive. With nonpower-driven rollers the movement of the load in the horizontal position of the rollers takes place under the action of the force (in jerks) applied to them, or with inclined rollers by gravity.

Power-driven rollers are used principally in rolling mills; in machine building nonpower rollers are used both in flow production and in other cases for transporting the elements between working places. If the elements do not have a flat surface they are transported in boxes, on trays, stands. Inclined rollways have an inclination of 2-3%.

If necessary rollways may be made with curvature; the smallest radius of curvature is 750 mm (for small loads); the average radius of curvature is 1100-1800 mm.

For changing the direction of the transported load, branching rollways (Fig. 152) are made, or switches (Fig. 153) are used, turntables with rollers, ball plates. If a considerable length of a rollway makes a passageway necessary, one section is hinged so that it can be lifted.

The rollway may be in the form of a continuous long roller table running along the working places, or in the form of individual short sections between machine tools and only connecting adjacent working places.

If it is necessary to transport elements in the reverse direction or to deliver various elements to the working places, the rollway is made in two rows or in two or three tiers.

The roller way is assembled from individual sections of length 1-3 meters each. The center to center clearance between rollers (spacing) is taken at 100-300 mm. The standard height of roller ways is 700-850 mm; for transporting large elements

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the height may be less (250-200 mm) depending on the size of the elements. The width of roller ways is 350-850 mm.

In a typical construction the diameter of the rollers is taken at 50-75 mm and the length at 300-600 mm. The rollers are usually made of seamless tubing and are mounted on ballbearings. The supports for the frame of the roller way are placed, depending on the loading, 1-2 meters apart.

Roller ways are widely used in flow production of mechanical and assembly shops of machine-building works.

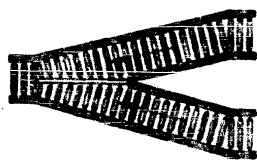


Fig.152 - Branching Roller Way

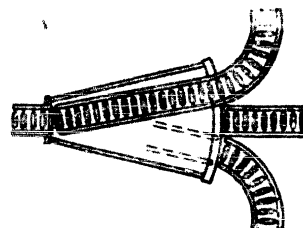
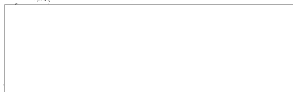


Fig.153 - Switch of Roller Way

For taking the elements from conveyors and roller ways and putting them on the machine tools, telfers and pneumatic hoists on monorails are used. Particularly convenient are pneumatic hoists, which are frequently used in automobile works; their lifting capacity reaches 1.75 tons, height of lift of load up to 1.8 meters; pressure of air in network 5-7 atm.

In flow production for transporting the elements between machine tools, ramps and slideways are used; they are so called because the elements are transported by rolling or sliding down.

Ramps are indicated for transporting cylindrical or spherical elements. They may be in the form of one or several inclined chutes or in the form of an inclined metal cascade with guides. Ramps are assembled from standard sections of length of 1.5-2 meters each. Depending on the weight and shape of the elements, they are



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given an inclination of 1:10 to 1:15; the length of the ramps reaches 10 meters; Slideways serve for transporting elements with a flat surface. They are made in the form of a metal chute with an inclination of 1:2 to 1:5.

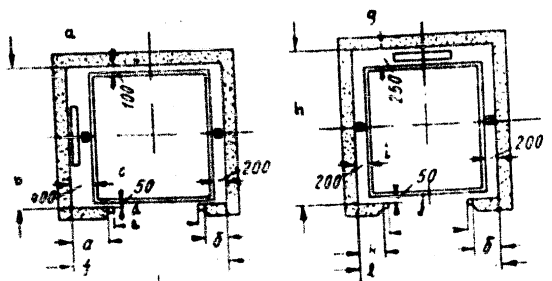


Fig. 15h - Schemes of Shafts for Freight Elevators

- a) Lateral counterweight; b) Depth of shaft; c) Not more than; d) Door; e) Opening; f) Width of shaft; g) Rear counterweight; h) Depth of shaft; i) Not more than; j) Door; k) Opening; l) Width of shaft

Freight elevators serve for vertical transport of loads in multistory buildings. The elevator is usually installed in a closed shaft. The lifting capacity of the elevators used in factories is 500-3000 kg, at which the dimensions of the cage are from 1500 x 1500 mm to 2500 x 3000 mm at a width of the door frame of 1400 to 2200 mm; the height of the cage is 2000 mm. The height of the machinery compartment for an elevator with a lifting capacity of 2000 kg or more is 2400 mm. Some schemes of shafts for elevators in plan are represented in Fig. 15h.

101. Load Flow

The load flow of a works or shop is the scheme of the movement through the shop or works of materials, semiproducts and products in accordance with the sequence of the stages of the production process. The scheme of the load flow shows

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to what extent, in the given production, the fundamental principle of the shortest path of movement of the materials and semiproducts in the process of their fabrication is observed and the production of products therefrom. The transport of the loads in one direction or the other takes place with various transport means, sometimes with one or several types thereof, sometimes with all of them combined. The better the just-mentioned fundamental principle of the shortest path of the materials and products is observed, the more proper is the load flow, and the better is the transport.

The load flow of the works shows the distribution and direction of movement of the loads through the shops and storerooms; the load flow of the shop the distribution and direction of movement of the loads through the working places and storerooms of the shop.

The total weight of the loads transported in a year or a day is determined for materials and blanks according to the rough weight and for finished elements and products according to the finished weight; the difference between these two weights represents the weight lost in transport.

The load flows, depicted graphically for individual departments and whole works, must show the entrance and movement of materials, blanks and semi-products with notations of their rough weight, and, finally, movement and exit of the finished products, expressed in their final weights.

Lines (or stripes) of the load flow depicts the direction of movement of the load flow and their thickness with the weights in corresponding scale.

In Fig.155, the scheme of the whole-works load flow of a large machine-building works are represented. In Fig.156 the scheme of the load flow of the mechanical and assembly shops located in a four-story building are shown.

102. Determination of the Necessary Number of Transport Means

For timely, proper and regular transport of the loads, it is necessary to assure the shops and whole-works of sufficient, suitable transport means. This is

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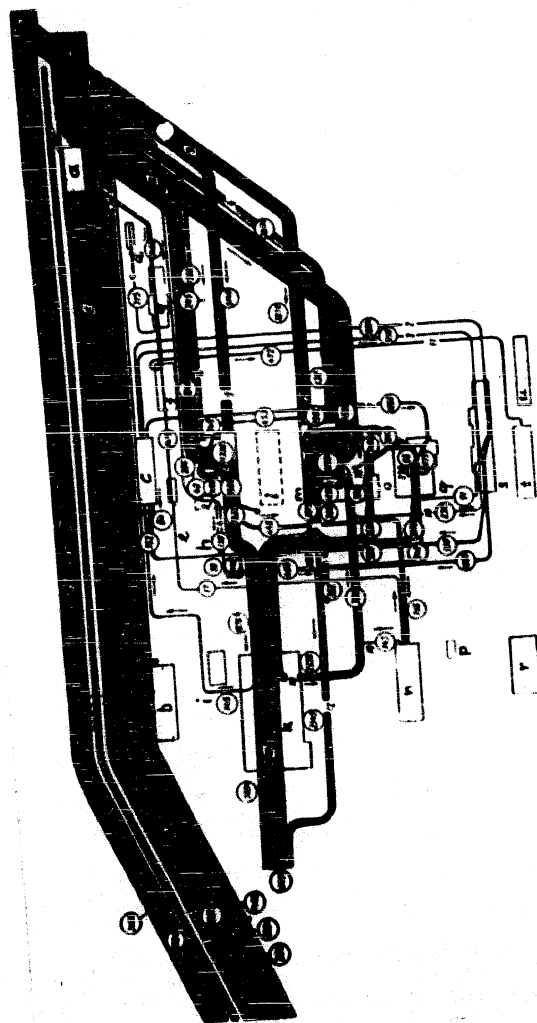


Fig.155 - Scheme of Whole-Works Load-Flow

1) Steel; 2) Sorted materials; 3) Iron; 4) Bronze; 5) Wood; 6) Fluxes, filling materials; 7) Coke; 8) Metal charges; 9) Molding materials; 10) Metal waste; 11) Wood waste; 12) Finished products.
 a) Freight station; b) Storage of finished products; c) Central storehouse; d) Construction shop; e) Pattern storage; f) Patternmaking; g) Drying; h) Charge yard; i) Tools; j) Iron foundry; k) Mechanical shop; l) Mold-box storage; m) Steel foundry; n) Mechanical and electrotechnical repairs; o) Heating; p) Storage of finishing materials; q) Forging; r) Electric station; s) Metal-construction shop; t) Generator station; u) Post Storage.

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determined by conditions of production, detailed calculation according to each form of transportation based on weights of loads to be carried and on experimental data.

Let us examine the method of the determination of the necessary number of

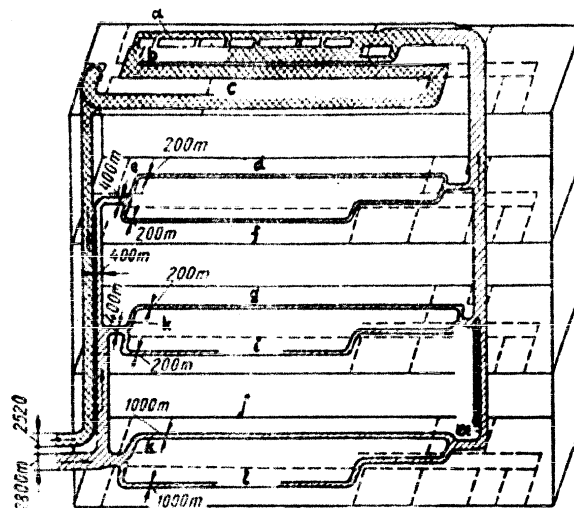


Fig.156 - Scheme of Load Flow of Mechanical and Assembly Shops
in Four-Story Building

bridge cranes according to the first method, i.e., by calculation on the basis of the weights of the transported loads and the number of crane operations. The calculation takes place in the following order.

1. The number of elements to be transported by the cranes in a year on the basis of the whole list of elements on the yearly production program is noted.
2. On the basis of the average number of transfers of all of the elements between working places, including storages, the total number of crane operations in a year for crane transportation of the elements is determined, which is obtained by multiplying the average number of transfers of all of the elements between working places by the number of elements to be transported in a year.

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3. According to the obtained number of operations, the number of crane operations per shift is determined; it is obtained by dividing the yearly number of operations by the total number of shifts for the total number of days in a year.

4. On the basis of the length of the technological line, the average length of travel of the crane (to and fro) per crane operation is determined.

5. Knowing the speed of movement of the crane from its characterization, the time necessary for the travel of the crane per crane operation is found by dividing the average length of travel of the crane (to and fro) per crane operation by the average speed of movement of the crane.

6. The obtained time necessary for the travel of the crane per crane operation must be multiplied by the number of crane operations per shift, as a result of which the time necessary for the travel of the crane per shift is obtained.

7. The time for loading the elements on and unloading them from the crane per shift is determined, which is obtained by multiplying the loading and unloading times of the crane per operation by the total number of operations per shift.

8. By summing the times of travel of the crane per shift and the times for loading and unloading the elements per shift, the total working time of the crane per shift is obtained.

9. By dividing the obtained total working time of the crane per shift into its actual time fund per shift the necessary calculated number of cranes is obtained, which in the case of a fractional number is rounded to a whole number, called the taken number of cranes.

10. By division of the calculated by the taken number of cranes, their coefficient of loading is determined.

This calculation may be carried out according to the formulas presented below.

The number of crane operations per year is:

$$J_g = D \cdot i$$

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Number of crane operations per shift:

$$J_{sm} = \frac{Di}{\Phi \cdot t};$$

$$T_{sr} = \frac{l}{v} \cdot \frac{Di}{\Phi t};$$

$$T_z = t_z \cdot \frac{Di}{\Phi t};$$

$$T_r = t_r \cdot \frac{Di}{\Phi t};$$

$$T = T_{sr} + T_z + T_r = \frac{Di}{\Phi t} \left(\frac{l}{v} + t_z + t_r \right);$$

$$K_r = \frac{T}{f_0} = \frac{T}{fk}; \quad (246)$$

$$K_r = \frac{Di}{\Phi t} \cdot \frac{\left(\frac{l}{v} + t_z + t_r \right)}{fk}; \quad (250)$$

$$\eta_k = \frac{K_r}{K_{pr}};$$

where D is the number of elements to be transported by the cranes in a year;

i is the average number of crane operations per element;

t is the number of working shifts per day;

l is the average length of path of the crane in meters (to and fro) per crane operation;

v is the average speed of movement of the crane in m/min;

T_{kr} is the travel time of the crane per shift in minutes;

T_z is the element loading time of the crane per shift in minutes;

t_z is the loading time of the crane per operation in minutes;

T_r is the element unloading time of the crane per shift in minutes;

t_r is the loading time of the crane per operation in minutes;

T is the total working time of the crane per shift in minutes;

f is the nominal time fund of the crane per shift in minutes (480 minutes);

k is a coefficient taking into account idleness of the crane for repairs (0.97);

f_0 is the actual time fund of the crane per shift in minutes;

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K_r is the calculated number of cranes;

K_{pr} is the taken number of cranes;

η_k is the coefficient of time loading of the crane;

ϕ is the number of working days per year;

J_g is the number of crane operations per year;

J_{sm} is the number of crane operations per shift.

It should be noted that if the cranes are unequally loaded in the shifts it is necessary to calculate each shift separately - according to the number of elements transported during the shift; the number of cranes is taken for the shift with the largest number of transported elements.

The coefficient of crane loading varies depending on the conditions of character of the production; for mechanical and assembly shops the average coefficient of loading is approximately 0.75.

For simplification the number of bridge cranes per aisle is determined on the basis of the length of the served aisle; thus, for example, for mechanical and assembly shops one crane for each 50-60 meters of aisle length is taken, and, for foundries and forging shops, one crane for each 40-50 meters.

The working load of the cranes is sometimes depicted in the form of a graph, in which the connection of their work in time and space must be reflected, i.e., the duration of the work of the cranes on individual operations, their lengths of travel, and the distribution of the places served by them, with indication of whether some of the cranes pass each others paths of movement. In the graph this is reflected in the following manner.

On the ordinate, the name of the crane is noted and, schematically, the positions of the working and storage places along the line of the assembly flow; the length of the horizontal line, parallel with the abscissa, allocated to each crane corresponding to its position in relation to the working (or storage) place determines the duration of the work of the crane at each working place. By joining these

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horizontal segments by vertical lines, the depiction of trips of the crane between places is obtained. In this way, a complete representation of the loading of the cranes and of their location relatively to each other during the working time is obtained.

The use of Formula (249) for calculating the necessary number of bridge cranes can be seen from the following example:

Example: Calculate the necessary number of 5-ton bridge-cranes in one aisle of a mechanical shop.

Given that 8000 elements a year of weight greater than 400 kg must be transported by the cranes (elements of smaller weight are transported by electric trucks). The average number of transfers of all of the elements between machine tools, including reloading in two storages, is taken at 5; this gives 5 operations per element. From this the number of crane operations in a year is determined at:

$$J_2 = Di = 5 \cdot 8000 = 40000.$$

or, at two-shift working and 307 working days in a year, the number of crane operations per shift will be

$$J_{2s} = \frac{Di}{\Phi_t} = \frac{40000}{307 \times 2} = 67$$

At an average of travel of the crane per operation of 45 meters and an average speed of movement of the crane of 50 m/min (maximal speed equals 110-120 m/min) we get for the travel time of crane per shift:

$$T_{2s} = \frac{l}{v} \cdot \frac{Di}{\Phi_t} = \frac{45}{50} \times 67 = 60 \text{ min}$$

Taking the loading and unloading time per crane operation at an average of 2 minutes, we get for the loading and unloading time of the elements per shift:

$$T_z + T_r = t_z \cdot \frac{Di}{\Phi_t} + t_r \cdot \frac{Di}{\Phi_t} = (t_z + t_r) \cdot \frac{Di}{\Phi_t} = 4 \times 67 = 268 \text{ min}$$

The total loading of the crane is

$$T = T_{2s} + T_z + T_r = 60 + 268 = 328 \text{ min}$$

At a crane time fund per shift of 480 minutes and a coefficient of loading of 0.97, taking into account its idleness for repairs, we find the calculated number

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of cranes at:

$$K_r = \frac{T}{f_k} = \frac{328}{480 \times 0.97} = 0.70.$$

The obtained fractional number of cranes is rounded to one crane. The coefficient of loading of the crane will be

$$\eta_k = \frac{K_r}{K_{pr}} = \frac{0.70}{1} = 0.70.$$

The calculation can be carried out according to the definitive Formula (249).

Substituting in it the given values, we get

$$K_r = \frac{8000 \times 5 \left(\frac{45}{50} + 2 + 2 \right)}{307 \times 2 \times 480 \times 0.97} = 0.70.$$

The calculation of the necessary number of electric trucks (as well as of other truck transports) takes place in an analogous manner, on the basis of the weight of the elements transported in a year, the travel time of the truck, and its loading and unloading time.

Denotation:

Q is the weight of the elements transported in a year in tons;

q is the load of the truck per trip in tons;

i is the average number of transport operations for all of the elements;

T_t is the travel time of the electric truck in a year for all of the transport operations in hours;

l is the average travel of the electric truck per trip to and fro in meters;

v is the average speed of the electric truck in m/min;

T_z is the loading time of the electric truck in a year in hours;

t_z is the loading time of the electric truck per operation in minutes;

T_r is the unloading time of the electric truck in a year in hours;

t_r is the unloading time of the electric truck per operation in minutes;

T is the total working time of the electric truck per year in hours;

F is the nominal yearly time fund of the electric truck in hours per shift

($8 \times 307 = 2456$ hours);

t is the number of working shifts of the electric truck per day;

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k is a coefficient taking into account the idleness of the electric truck for repairs (0.95);

K_r is the calculated number of electric trucks;

K_{pr} is the taken number of electric trucks;

η_t is the coefficient of time loading of the electric truck.

Then we get:

the number of transport operations per year $J_q = \frac{Ql}{q}$;

$$T_t = \frac{t}{v \cdot 60} \cdot \frac{Ql}{q};$$

$$T_z = \frac{t_z}{60} \cdot \frac{Ql}{q};$$

$$T_r = \frac{t_r}{60} \cdot \frac{Ql}{q};$$

$$T = T_t + T_z + T_r = \frac{Ql}{q} \left(\frac{t}{v} + \frac{t_z}{60} + \frac{t_r}{60} \right); \quad (251)$$

$$K_r = \frac{T}{Ftk} = \frac{Ql}{q \cdot 60 Ftk} \left(\frac{t}{v} + t_z + t_r \right);$$

$$\eta_t = \frac{K_r}{K_{pr}}.$$

(252)

Example: All of the elements weighing up to 100 kg are transported in the shop by electric truck; small elements in boxes, large ones in bulk on the platform of the trucks; total weight of transported elements per year 3000 tons.

Given that the number of transfers of the elements between machine tools and the transport of blanks from shop storage and of treated elements to intermediate storage, we get on the average five transport operations per element. Given further that the load of the electric truck per trip is on the average 0.40 ton.

Then the total number of transport operations per year is

$$J_q = \frac{Ql}{q} = \frac{3000 \times 5}{0.40} = 37500.$$

Given in the present case that the average travel of the electric truck to and

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from is

$$l = 45 \times 2 = 90 \text{ m}$$

At an average speed of the electric truck $v = 100 \text{ m/min}$ we get

$$T_t = \frac{l}{v} \cdot \frac{Q}{q} = \frac{90}{100 \times 60} \cdot 37500 = 563 \text{ hrs}$$

The total time for all of the operations per year at:

$$T_z + T_r = \left(\frac{l_z + l_r}{60} \right) \cdot \frac{Q}{q} = \frac{10}{60} \times 37500 \approx 6250 \text{ hrs}$$

The total working time of the electric trucks is

$$T = T_t + T_z + T_r = 563 + 6250 = 6813 \text{ hrs}$$

At a nominal yearly electric-truck time-fund of 2456 hours, two working shifts, and a coefficient $k = 0.95$, we get the number of necessary electric trucks at:

$$K_r = \frac{T}{F \cdot k} = \frac{6813}{2456 \times 2 \times 0.95} = 1.5;$$

rounding gives us two electric trucks.

At this the coefficient of loading of the electric trucks will be

$$\eta_t = \frac{1.5}{2} = 0.75.$$

The calculation of the number of electric trucks can also be carried out directly according to the definitive Formula (251):

$$K_r = \frac{3000 \times 5}{0.40 \times 60 \times 2456 \times 2 \times 0.95} \left(\frac{90}{100} + 10 \right) = 1.5.$$

From the two examined examples of the calculation of the number of cranes and electric trucks it is seen that the time expended directly on travel of the crane or electric truck is comparatively small, and that a considerable part thereof goes for loading and unloading the used transport. This is often the case in the actuality.

This situation must be borne in mind, and every possible organizational-technical measure must be taken for reducing the loading and unloading, thereby increasing the actual utilization of the transport means.

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CHAPTER XVIII

FUNDAMENTAL DATA FOR PLANNING OF INDUSTRIAL BUILDINGS

111. Types, Constructions and Principal Dimensions of Buildings for Shops of Machine-Building Works

The type, construction and dimensions of buildings for shops are selected depending on the following factors:

- (a) Character and size of the objects of production, volume of program and technological process;
- (b) Types and sizes of lifting cranes and transport means;
- (c) Requirements with respect to lighting, heating, ventilation;
- (d) Conditions of removal and disposal of atmospheric deposits;
- (e) Provision for possible later enlargement of building.

Industrial buildings may be one-story or multistory.

Buildings for machine-building shops are preferably one-story, because in this production heavy equipments are used, and the products themselves are characterized by great weight and large over-all dimensions.

However, where it is possible according to the character of the manufactured products and the used equipments, and particularly in the technic-economic respect, it is advantageous to adopt multistory buildings.

One-Story Buildings

Industrial one-story buildings in the majority of cases consist of several par-

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allel aisles of the same type formed by rows of columns - metal or reinforced concrete. Such multiaisle buildings give the possibility of enclosing a greater production area.

The form of the one-story industrial building must be the simplest, in the form of a rectangle (or square), because the cost of the building is increased by complicated constructions. However, on the basis of the conditions of the production process, ventilation, lighting, the necessity of avoiding interior gutters, and also other considerations, it is necessary to adopt for some shops (forging, pressing, etc.) buildings of complicated form - in form of 2 or 3 parallel wings, etc.

The total size and area of the shops are determined on the basis of the plan of the equipments and all the rooms of the shop. The dimensions of a building consisting of several aisles is determined by the dimensions and the number of aisles.

Each aisle of the shop is characterized by the principal dimensions: width of aisle L and spacing of columns t , or, in other words, by the network of columns $L \times t$.

The width of the individual aisles of the building is determined on the basis of the plan of the equipments depending on the size of the fabricated elements, the used equipments and transport means. The width of the aisle of the building L is defined as the center to center clearance between upper overcrane pillars or between columns (Fig.162). The width of the aisles of the building is usually taken in multiples of 3 m.

The spacing of the columns is defined as the center to center clearance between two columns in the direction of the longitudinal axis of the aisle.

By definition the width of the aisle of the building is a fixed dimension dependent on the span of the bridge crane.

The span of the bridge crane L is defined as the clearance between the vertical axis of the crane rails (Fig.162)

The width of the aisle of the building L is determined by the formula

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$$L = L_k + 2l,$$

where l is the clearance from the axis of the undercrane pillar to the vertical axis of the crane rail.

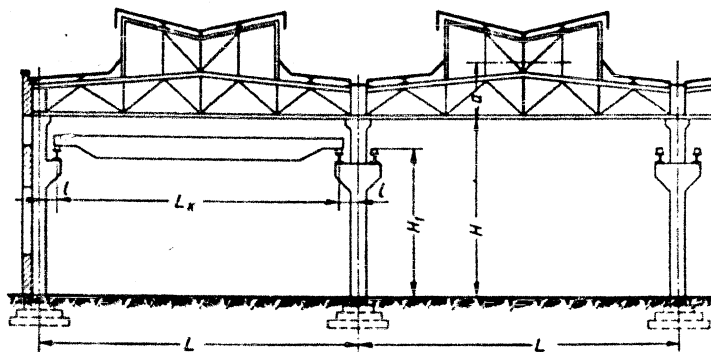


Fig. 162 - Scheme of Aisles

The dimensions (by definition) depend on the lifting capacity of the crane.

The gradations of the spans of the building and the spans of the cranes are presented in Table 53. In allocating several cranes of various lifting capacities to the same path the span of the crane is taken according to the crane of the greatest lifting capacity. At two-tier location of cranes the span shown in the Table relates to the crane of the upper tier.

The dimension of the clearance l from the axis of the column to the vertical axis of the crane rail is composed of the following values (Fig. 163):

- (1) The dimension t from the axis of the column to its edge at the place where the undercrane rail is located;
- (2) The dimension s of the interval between the column (or wall) and the end of the projecting part of the crane, which is (according to GOST 3332-46) taken at 60 mm;

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(3) The dimension b between the end of the space requirement of the crane and the axis of the undercrane path; the value of this dimension depends on the size of

Table 53

Spans of Building and Cranes

a)	b)			a)	b)		
	to 15	20-75	above 75		to 15	20-75	above 75
6	5	-	-	21	20	19.5	19
9	8	7.5	-	24	23	22.5	22
12	11	10.5	10	27	26	25.5	25
15	14	13.5	13	30	29	28.5	28
18	17	16.5	16	33	32	31.5	31

a) Span of Building L in meters; b) Span of Crane L in meters at Lifting Capacity of Crane in Tons

the crane:

for crane of lifting capacity up to 15 tons, 230 mm

for crane of lifting capacity up to 20 tons, 260 mm

for crane of lifting capacity up to 30 tons, 280 mm

for crane of lifting capacity up to 50 tons, 280 mm

According to the given notation

$$L = L_s + 2l = L_s + 2(t + s + b). \quad (264)$$

Accordingly for cranes of lifting capacity up to 15 tons

$$2(t + s + b) = 1000 \text{ mm};$$

for cranes of lifting capacity 20-75 tons

$$2(t + s + b) = 1500 \text{ mm};$$

for cranes of lifting capacity over 75 tons

$$2(t + s + b) = 2000 \text{ mm}.$$

Since the values of s and b are taken according to GOST, the values of t are determined from the presented equalities, and hence also the dimensions at $2t$ of the

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columns in the direction of the width of the span.

In the selection of the width of the span of the building and the establishment of the necessary dimensions between the axes of the undercrane paths, it must be

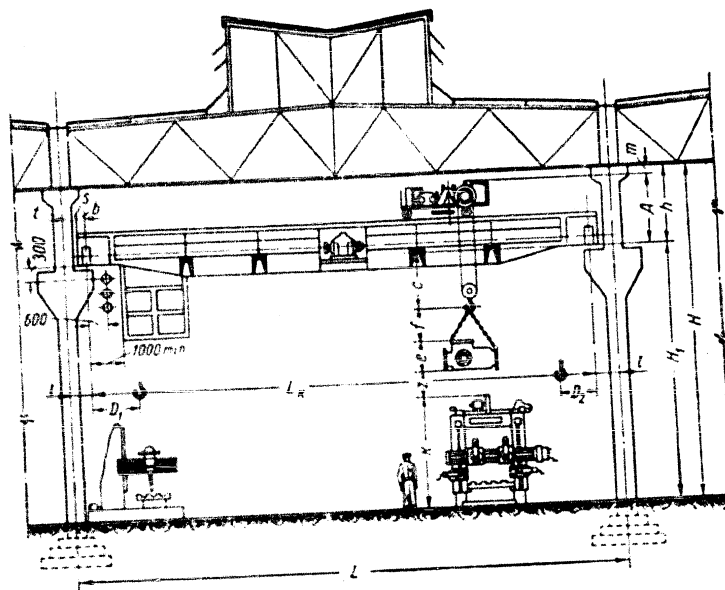


Fig.163 - Scheme for Determining Width and Height of Shop Span

borne in mind that in the end position of the truck the crane hook comes short of reaching the axis of the undercrane rail by the distances D_1 and D_2 (Fig.158). The clearance from the end position of the hook to the axis of the undercrane rail depends on the size of the crane, and is not the same for the main and the auxiliary hook; this clearance also depends on the side of the crane on which the hook is present.

Below are presented the greatest distances in mm for the main hook D_1 and the auxiliary hook D_2 by which they come short of reaching the vertical axis of the undercrane rail:

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for 5-ton cranes with one hook	1050
for 10- and 15-ton cranes with one hook	1100
for 15- and 20-ton cranes, for main hook	1650
for 15- and 20-ton cranes, for auxiliary hook	1750
for 30-ton cranes, for main hook	1700
for 30-ton cranes, for auxiliary hook	2300
for 50-ton cranes, for main hook	1850
for 50-ton cranes, for auxiliary hook	2300

The enumerated clearances must be taken into account at the selection of the dimension of the span of the building and at the spacing of the machine tools around the columns if these machine tools must be served by the crane; at close location of the machine tools to the columns (and more so in the intercolumn intervals) the hook chain will not reach the middle of the machine tool, so that the crane cannot be used. It should be noted that lifting a load with the crane with a guy hook off center is prohibited by the safety rules of the art in view of the danger of being hit by the lifted load.

The dimension of the span for various shops, depending on the kind of machine building and the character of the work carried out, is taken at: 9-36 meters for mechanical and assembly shops; 12-30 meters for foundry shops; 15-30 meters for forging shops.

The dimensions of the individual spans of the mentioned shops that are most frequently adopted for various branches of machine building and various kinds of work are reported in the corresponding chapters of the book.

The spacing of the columns for all shops and dimensions of spans is usually taken at 6 meters, while in some cases (for metal construction) the spacing of the columns reaches 12 meters.

The length of the shop aisle is determined by the sum of the dimensions of the production and auxiliary departments following each other along the aisle, the pas-

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sageways, and other parts of the shop.

The principal dimension determining the length of the aisle is the length of the technological line of machine tools located along the aisle.

The length of the shop aisle, determined graphically on the basis of the plan of the equipments and all of the departments and parts located along the aisle is, at a typical scheme of the components (Fig.184), composed of the following dimensions:

- (1) The width of the shop storage for materials and blanks or of the shop area for blanks at the beginning of the machine-tool line (the shop storages, as already mentioned, are usually located across the aisles of the shop, and it is only sometimes, when the direction of the production flow is perpendicular to the longitudinal axis of the aisles, that they are located along the aisles);
- (2) The width of the transverse passageways between these storages and the machine-tool department (3-4 meters);
- (3) The length of the machine-tool department with transverse passageways for transport of products and movement of persons (3-4 meters);
- (4) The width of the transverse passageway in front of the checking department;
- (5) The width of the checking department if it is located across the aisles of the building;
- (6) The width of the intermediate storage (at its usual location across the aisles of the building).

The total length of the shop must be a multiple of the value of the spacing of the columns, i.e., 6 meters. Otherwise a correction must be introduced into the plan of the shop for taking into account the increased or decreased dimensions of the parts located along the axis of the aisle.

The height of the shop aisle is determined on the basis of the size of the produced products, the over-all dimensions of the equipments (in height), the size and construction of the bridge cranes, and also the sanitary-hygienic requirements.

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The total height of the building H (Fig.158), from the floor to the lower projecting parts of the ceiling or to the lower points of the footing beams is composed of the distance H_1 (Fig.158), from the floor to the head of the undercrane rail and the distance h from the head of the rail to the lower projecting parts of the ceiling or to the lower points of the footing beams, which depends only on the construction of the crane and its over-all height.

The value of H_1 is determined according to the formula

$$H_1 = k + z + e + f + c, \quad (265)$$

where K is the height of the highest machine tool; if the machine tools are low, this dimension is taken at not less than 2.3 meters, i.e., somewhat greater than the height of a man;

z is the interval between the transported product lifted in the end top position and the top point of the highest machine too; this interval must be not less than 400-500 mm.

e is the height of the largest product in the transporting position;

f is the distance from the upper edge of the largest transported product to the center of the crane hook in its upper position necessary for seizing the product with the chain or cable depending on the size of the product; it is taken at not less than 1 meter, but may be greater;

c is the distance from the limiting upper position of the hook to the horizontal line passing through the tops of the rail heads; it is taken according to the standards of electric bridge cranes. For cranes of lifting capacity 5, 10 and 15 tons (with one hook) the dimension c is not taken into the calculation because the hook in its extreme upper position is higher than the undercrane rail; the value of c for 15-ton cranes with two hooks is 600 mm, for 20-ton cranes 400mm, for 30-ton cranes 300 mm, for 50-ton cranes 200 mm.

If there is an insignificant number of high machine tools in the aisle, the height of the aisle may be taken without taking into account the possibility of the

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transportation of elements above the highest machine tools; at this there must only be assured the possibility of passage of the crane above these machine tools.

The height H_1 from the floor to the rail head obtained in this way will be the minimal value.

The smallest height for the shop having a bridge crane must be not less than 5.75-6.0 meters; often, however, depending on the kind of production and the dimensions of the equipments, it is considerably greater, and reaches up to 18 meters.

The second part of the height of the aisle h is determined by depending on the construction and size of the crane; it equals the sum of the over-all height of the crane (Fig.158) and the clearance between the upper point of the crane and the lower points of the footing beams, i.e.,

$$h = A + m. \quad (266)$$

The over-all heights A of electric bridge cranes depending on the lifting capacity of the cranes are established in GOST 3332-46 as follows:

for cranes of lifting capacity 5 tons	1650 mm
for cranes of lifting capacity 10 tons	1900 mm
for cranes of lifting capacity 15 & 20 tons	2100 mm
for cranes of lifting capacity 30 tons	2350 mm
for cranes of lifting capacity 50 tons	2700 mm

The distance between the upper point of the crane and the lower points of the ceiling (or footing beams) m must be not less than 100 mm (at a trolley wire in the assembly).

Accordingly the total height of the aisle from the floor to the lower points of the ceiling H is

$$H = H_1 + h. \quad (267)$$

Besides this, the requirements of a sanitary-hygienic character must be observed, according to which not less than 13 cubic meters of production space and not less than 4 square meters of area must be provided for each worker; the height

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of the production rooms must be not less than 3.25 meters from floor to ceiling, and the height from the floor to the projecting parts of the construction of the building not less than 2.5 meters (NSP 101-51).

The height of the production room also depends on the width of the aisles: the wider the aisle is, the greater must be its height; at a small height and a great width of the aisle, insufficient and unequal lighting of the shop is obtained. On the basis of the foregoing considerations, the optimal height for buildings of various constructions corresponding with the width of the aisles can be established.

The necessary principal dimensions of the aisle established in this way - its width, height and spacing of columns corresponding to the conditions of the given production, are applied to typical structural sections suitable for the purpose.

The construction of the building is principally influenced by the following factors: the purpose of the building, its size, the lifting capacity of the cranes, character of the production process of the used equipments, the kind of building materials used.

In large aisles and powerful cranes, metal construction of the building should be adopted, consisting of metal columns and undercrane paths and metal roof trusses. In aisles of size not greater than 18 meters, reinforced-concrete constructions may also be adopted, consisting of reinforced-columns tied with the frame, undercrane track and a reinforced-concrete roof. In aisles of width greater than 18 meters, reinforced-concrete columns and beams become too heavy, so that metal construction is adopted in such cases.

Mixed construction may consist of reinforced-columns and metal trusses; in this case the width of the aisles may be 30 meters and more; such constructions are widely used.

Reinforced-concrete constructions are assembled from: columns spaced 6 meters apart, beams in spans up to 12 meters, trusses in spans up to 24 meters.

Metal constructions, made wholly of metal (columns, beams, roof, trusses, lan-

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terns, etc.) may be adopted for all shops for hot and cold working of metals. It is particularly necessary to adopt such a metal construction for buildings:

- (a) With cranes with a lifting capacity greater than 20 tons;
- (b) With travelling bracket cranes;
- (c) In aisles of 30 meters or more;
- (d) At height of columns greater than 12 meters;
- (e) In which metal constructions may be used for carrying the construction;
- (f) In which heating of the carrying construction may have a destructive influence on the reinforced concrete.

The principal material for metal construction is mark St.3 steel. Steel construction is preferably done by welding with butts on bolts and welding.

Mixed constructions consisting of reinforced-concrete columns and metal constructions may also be adopted for buildings of shops for hot and cold working:

- (a) For building with a 12 x 6 meter column network without cranes and with cranes of lifting capacity up to 3 tons, with T-form reinforced-concrete columns, lanterns of metal construction, girders thereon, and lantern sashes;
- (b) For buildings with a 12 x 6 and 15 x 6 meter column network with cranes of medium lifting capacity, with reinforced-concrete columns and metal trusses, girders, lanterns and lantern sashes;
- (c) For buildings with column networks of 18 x 6, 21 x 6, 24 x 6, 27 x 6 and 30 x 6 meters without cranes and with cranes of medium lifting capacity with reinforced-concrete columns and metal trusses, girders, lanterns and lantern sashes;
- (d) For buildings with a column network of 12 x 12 meters without cranes, with reinforced-concrete columns and light metal construction of the roof.

The undercrane beams with reinforced-concrete columns for cranes of medium lifting capacity are preferably made of reinforced-concrete and in the remaining cases of metal assemblies.

Metal undercrane beams are adopted in all cases where the clearance between the STAT

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supports of these beams is greater than 6 meters.

For the roof of industrial buildings, reinforced-cement plates are used, for the floor asbestos-cement plates, asbestos, cement corrugated-sheets, reinforced-pitch-concrete plates.

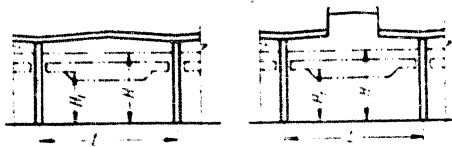


Fig.164 - Typical Sections of One-Story Industrial-Buildings with Interior Water Drainage

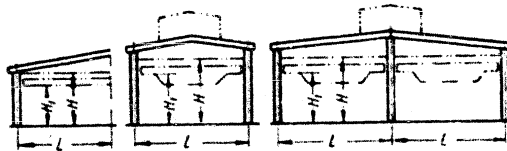


Fig.165 - Typical Sections of One-Story Industrial Buildings with Exterior Water Drainage

From the viewpoint of utilization of the shop area, a large column network gives a better index: the specific area, i.e., the area per machine tool is smaller in a larger network; moreover, a large network gives greater possibilities in planning the equipments because there are fewer columns.

As already mentioned, in correspondence with the necessary principal dimensions of the aisles of the building the construction of the structural sections corresponding to the given production must be selected.

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Table 5b

Typical sections of one-story industrial-buildings with interior drainage of rain water from roof and lifting-transport equipment used for buildings (Fig.164).

Column Network L x t in Meters	Height of Aisle in Meters		Lifting-Transport Equipment	
	H	H ₁	Name	Lifting Capacity in Tons
12 x 6	5;6		telphe; suspended boom crane	1;2
	5;6	4;5	boom crane	2;3
	6.9; 7.9	5;6	bridge crane	5
12 x 12	5;6		telphe; suspended boom crane	1;2
15 x 6	5;6		telphe; suspended boom crane	1;2
	8.1;9.1;10.1	6;7;8	bridge crane	5;10
15 x 12	5;6		telphe; suspended boom crane	1;2
18 x 6	5;6;7		telphe; suspended boom crane	1;2
	8.1;9.1;10.1;11.1	6;7;8;9	bridge crane	5;10
	7.3;10.3;11.3	7;8;9	" "	20/5
	11.6;12.6	9;10	" "	30/5
18 x 12	5;6;7		telphe; suspended boom crane	1;2
21 x 6	6;7;8		telphe; suspended boom crane	1;2
	9.1;10.1;11.1;12.1	7;8;9;10	bridge crane	5;10
	10.3;11.3;12.3	8;9;10	" "	20/5
	11.6;12.6;14.6	9;10;12	" "	30/5
	13;15	10;12	" "	50/10
24 x 6	6;7;8		telphe; suspended boom crane	1;2
	9.1;10.1;11.1;12.1	7;8;9;10	bridge crane	5;10
	10.3;11.3;12.3	8;9;10	" "	20/5
	12.6;14.6	10;12	" "	30/5
	13;15;17	10;12;14	" "	50/10

- Remarks: 1. For bridge cranes with a trolley wire the assembly is located below the bridge crane.
2. The Table is composed according to data of the KTIS of the Ministry of Building Undertakings of Heavy Industry.

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Table 55

Typical sections of one-story industrial buildings with exterior drainage of rain water from roof and lifting-transport equipment used for buildings (Figs. 165 and 166).

Column Network L x t in Meters	Height of Aisle in Meters		Lifting-Transport Equipment	
	H	H ₁	Name	Lifting Capacity in Tons
6 x 6	3.5;4.0		telfher	1
9 x 6	4.0;4.5;5.0	4.0	telfher;suspended boom crane	1
	5.0		boom crane	2;3
12 x 6	4.0;4.5;5.0;5.5;6.0		telfher;suspended boom crane	1
	5.0;5.5;6.0	4.0;4.5;5.0	boom crane	2;3
12 x 6	4.5;5.0;5.5;6.0		telfher;suspended boom crane	1;2
	5.0;5.5;6.0	4.0;4.5;5.0	boom crane	2;3
(12 + 12) x 6	6.9;7.9	5.0;6.0	bridge crane	5
15 x 6	5.0;6.0		telfher;suspended boom crane	1;2
	8.1;9.1;10.1	6.0;7.0;8.0	bridge crane	5;10
(15 + 15) x 6	5.0;6.0;7.0		telfher;suspended boom crane	1;2
18 x 6	8.1;9.1;10.1;11.1	6.0;7.0;8.0;9.0	bridge crane	5/10
	9.3;10.3;11.3	7.0;8.0;9.0	" "	20/5
(18 + 18) x 6	11.6;12.6	9.0;10.0	" "	30/5
21 x 6	6.0;7.0;8.0		telfher;suspended boom crane	1;2
	9.1;10.1;11.1;12.1	7.0;8.0;9.0;10.0	bridge crane	5;10
(21 + 21) x 6	10.3;11.3;12.3	8.0;9.0;10.0	" "	20/5
	11.6;12.6;14.6	9.0;10.0;12.0	" "	30/5
24 x 6	13.0;15.0	10.0;12.0	" "	50/10
	6.0;7.0;8.0		telfher;suspended boom crane	1;2
(24 + 24) x 6	9.1;10.1;11.1;12.1	7.0;8.0;9.0;10.0	bridge crane	5;10
	10.3;11.3;12.3	8.0;9.0;10.0	" "	20/5
	12.6;14.6	10.0;12.0	" "	30/5
	13.0;15.0;17.0	10.0;12.0;14.0	" "	50/10

Remarks: 1. For bridge cranes with a trolley wire the assembly is located below the bridge crane.

2. The Table is composed according to data of the KTIS of the Ministry of Building Undertakings of Heavy Industry.

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Some typical structural organizations for industrial buildings with interior and exterior drainage of the rain water from the roof have been formulated; their characteristics, including the network dimensions, lifting capacities of the lifting-transport means and heights are presented in Tables 54 and 55; the schemes of some typical sections are depicted in Figs. 164, 165 and 166.

In Fig. 167 the scheme of a typical building with interior water drainage used for various shops is presented. The width and height of the aisles can be varied in correspondence with the dimensions of the typical sections (Table 54).

Multiaisle buildings with interior drainage of the rain water give the possibility of enclosing a considerable area and are unlimited with respect to enlargement of the building by the addition of similar aisles. With such a roof the rain water runs into the building for draining in pipes running along its columns or inside the columns and connected with the drainage system located under the building. The underground part of the drainage network is made of cast-iron or concrete pipe.

In interior drainage one funnel per approximately 250-300 square meters roof area at a diameter of the leaders (vertical pipes) of 100 mm and a clearance between funnels of not more than 2 1/2 meters is provided. In a diameter of the leaders of 125 mm one funnel to approximately 550 square meters of roof area is taken.

Buildings with exterior drainage of the rain water enable enclosure of a smaller area and are limited with respect to the possibility of further enlargement by the addition of aisles. This type of roof, having a simple form and a low maintenance, has, however, the disadvantage that for obtaining the necessary pitch in the great width it is necessary to raise the top of the roof, which increases the volume of the building and therewith its cost of construction.

Cross sections of buildings of metal and reinforced-concrete construction with two-slope roofs and transverse lanterns are depicted in Figs. 168 and 169.

A multiaisle building of light construction with T-form columns and internal water drainage, as used with bridge cranes, is represented in Fig. 170.

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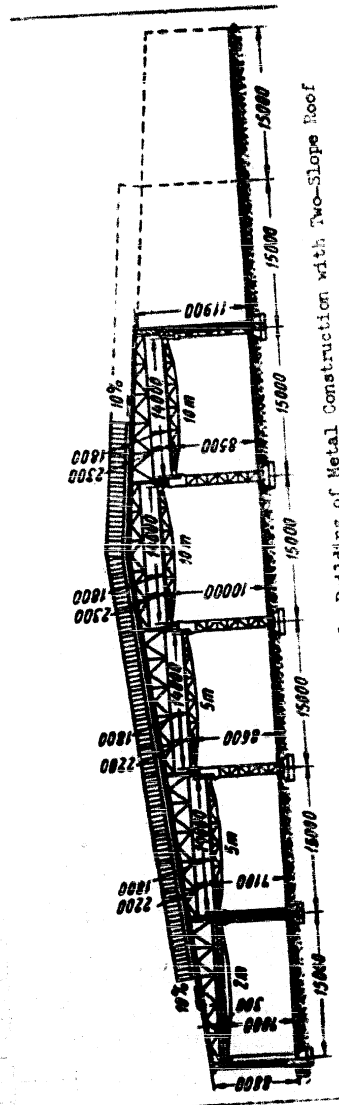


Fig. 168 - Cross Section of Five-Aisle Building of Metal Construction with Two-Slope Roof

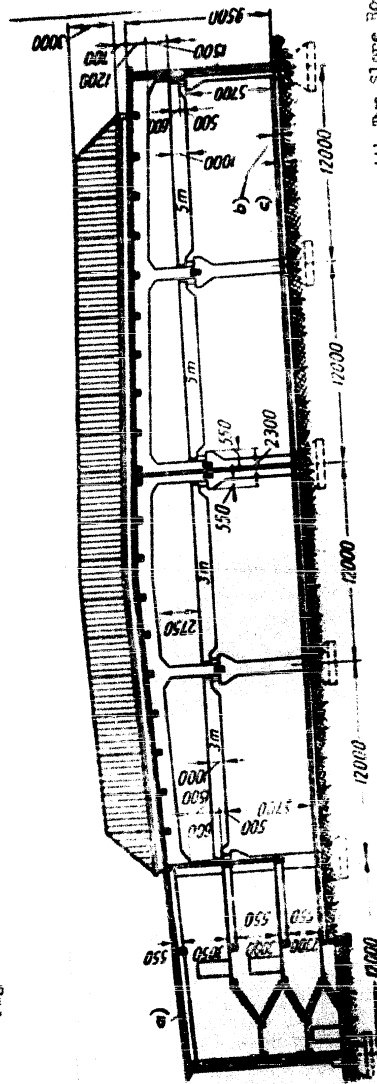


Fig. 169 - Cross Section of Four-Story Building of Reinforced-Concrete Construction with Two-Slope Roof

a) Two layers of; b) Concrete; c) Blocks



Fig. 169 - Cross Section of Four-Story Building

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In Fig.171 the cross section of the building of an iron-foundry shop made of reinforced-concrete segments is represented and in Fig.172 the cross section of a building of metal construction for force shops and other hot-working shops.

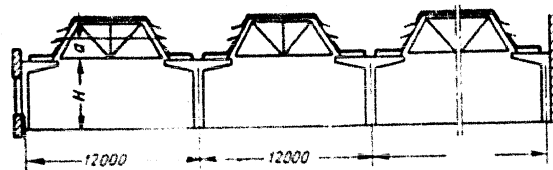


Fig.170 - Scheme of Multiaisle Building with T-Form Reinforced-Concrete Columns and Interior Water Drainage

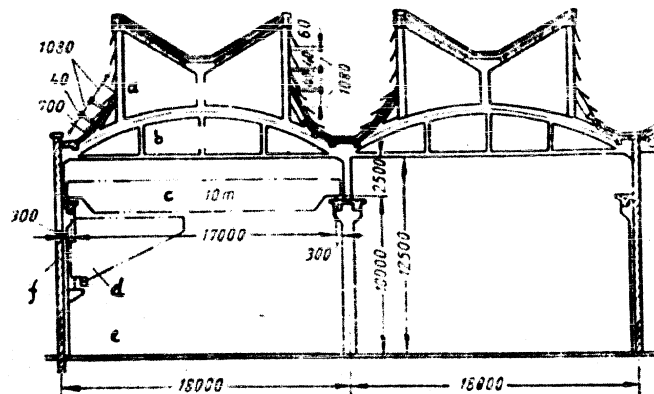


Fig.171 - Cross Section of Building of Iron-Foundry Shop with Segmented Trusses of Reinforced Concrete

a) Reinforced-concrete lantern-frame; b) Reinforced-concrete arch; c) 10-ton crane; d) Bracket crane; e) Molding department; f) Core department

In Fig.172 the cross section of a building for metal construction for mechani-

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cal and assembly shops is represented; in the aisle of the assembly shop bridge cranes of lifting capacity 100 and 30 tons are located in two tiers.

On the basis of analysis of typical schemes of industrial buildings, a suitable

scheme can be selected and the expenditures of metal and concrete ("Planning of Industrial Enterprises" under the general editorship of P.M.Frenkel, published by Gosstroizdat, 1952) determined approximately;

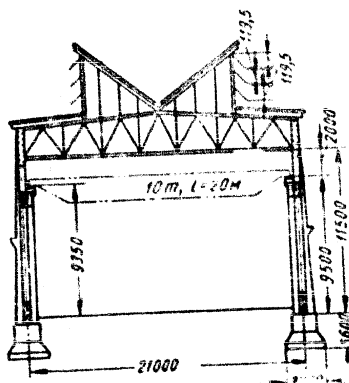


Fig.172 - Metal Construction for Mechanics Shop and Assembly

1. For buildings with an all-metal framework in the absence of bridge cranes in an optimal column spacing of 18×12 meters; the expenditure of steel (mark St.3) per square meter building area comes to 38.5-55.9 kg depending on the loading of the roof and the presence of suspended lifting-transport equipment.

2. For buildings with an all-metal framework in the presence of bridge cranes the great span (according to the state of the art) should be taken with a column spacing of 6 meters; the expenditure of steel per square meter building area is 55.5-100.8 kg in cranes of lifting capacity up to 50 tons; the height from the floor to the head of the undercrane rail is 6-12 meters, in self-supporting walls and in rectangular skylights only in the intermediate aisles.

3. For buildings of mixed construction (reinforced-concrete columns, metal roof) in the presence of bridge cranes the optimal size of the aisle is 18 meters; the expenditure of steel per square meter building area for this aisle at column spacing 6 meters is 35.7-48.0 kg depending on the presence of suspended lifting-transport equipment and the loading of the roof; the expenditure of concrete per

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square meter building area is 3.1 to 4.4 cubic meters.

4. For buildings of mixed construction in the presence of bridge cranes the greatest span (according to the conditions of the technology) is taken at a column spacing of 6 meters; the expenditure of steel per square meter building area is 51.2-77.6 kg, that of concrete 6.1-15 cubic meters, depending on the lifting capacity of the cranes (5-20 tons), the height of the building (6-9 meters) and the loading of the roof (160-400 kg/square meter).

Multistorey Buildings

As already mentioned, where the conditions of the production permit it, and it is advantageous from the technico-economic standpoint, multistorey buildings are adopted. For the production of light and medium products, as, for example, cutting tools, measuring implements, apparatus, adding machines, perforators, typewriters, sewing machines, carburetors, phonographs, etc. there may be adopted for the mechanical and assembly shop buildings of 2-5 stories and sometimes of more. Shops liberating large quantities of heat or harmful gases should be located on the upper floors of multistorey buildings.

With multistorey buildings the greatest concentration of manufacturing space on the grounds of the building is obtained, a shortening of the communication lines and the intraworks distances, a smaller expenditure on fencing the grounds, landscaping and maintaining it. With multistorey buildings the production can be housed in sections of limited size. However, in the housing of mechanical shops in multistorey buildings there is a limit to the possibility of locating machine tools on the upper floors.

The permissible loading of the floors of multistorey buildings is usually taken at 700-800 kg/square meter (not higher than 1000-1200 kg/square meter); a greater loading greatly increases the cost of the building. For comparison it may be noted that for floors built on ground of normal density the permissible loading is up to 2500 kg/square meter. With dense ground the loading may be considerably greater.

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For shops making heavy products and having heavy machine tools the permissible loading of the ground at suitable fastening is up to 10,000 kg/square meter. For productions with small and medium machine tools a loading capacity of the floor of 1000 kg/square meter is reached, and in large machine tools up to 2000 kg/square meter.

The above mentioned loadings of the floors of multistory buildings are sufficient for the placement of the small and medium machine tools necessary for the productions housed in such buildings; the heavier and faster machine tools, and those operating with shocks (planing, slotting, etc. machines) should be placed on the first floor. If, on the basis of the technological flow it is found necessary to place heavy machine tools on the upper floor, then the carrying constructions of the building and the intermediate floors must be strengthened, taking the permissible loading in accordance with the weight of the installed equipments.

The placement of highspeed machine tools (lathes, grinding, etc. machines) on the upper floors requires a rigid construction of the floors (reinforced-concrete floors); on elastic vibrating floors the machine tools do not give the necessary precision of treatment, and, besides, they transmit their vibration to the other floors, which is, in its turn, reflected on the operation of the other machine tools.

The width of multistory buildings cannot be great, because it is limited by the possibility of good lighting from the sides. On this basis the width of a multistory building is usually taken at 18, 19, or 20 meters. The location of the working places and machine tools must be the optimal with respect to lighting by natural light.

A suitable relative location of the production and auxiliary departments of the shop, connected with each other in the sequence of the technological process, is more difficult to obtain with multistory buildings because of their limited width and the necessity of providing firewalls at standard intervals of the floor area, and also because of the necessity of observing a certain distance from any point of

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the room to the stairway enclosed in the stair well. The size of the floor areas bounded by firewalls is established by the standards of building planning depending on the number of stories and the fire-resistance of the building, the fire hazard inherent in the production (category of production) and on the presence or absence of a sprinkler system (compare further Table 60) (NSP 102-51).

Multistory industrial-buildings of the above-mentioned widths of 18, 19 and 20 meters, which are the most widely used, usually consist of three aisles, the two end ones of which are wider, and the third one, the middle one, is narrower (Fig.173). The most convenient for placing equipments are the aisle widths 7.5 and 8 meters in combination with a middle aisle of width 3 or 4 meters at a column spacing (reinforced concrete) of 4, or 5 or 6 meters (Table 56).

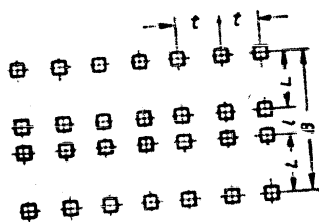


Fig.173 - Scheme of Production Aisles of Multistory Building

At two end aisles of 7.5 meters each and a middle one of 3 meters the width of the building is 18 meters; at two end aisles of 8 meters each and a middle one of 3 or 4 meters the width of the building is 19 or 20 meters.

With such layouts 3- or 4-meter aisles are provided for main passageways; in the end aisles of width 7.5 or 8 meters the equipments are placed; this gives the

most rational utilization of the area. The section of the reinforced-concrete columns is usually 400 x 400 mm. The simplest and most convenient form of multistory building is that of a rectangle, but depending on the dimensions of the building, the technological flow and the structural parts of the building, the form of two or three parallel wings or some other form is sometimes adopted.

The location of the stair wells may be either exterior (in annexes) or interior (a part of the building) (Fig.174). In the first case the internal area is better

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Table 56

Dimensions of Column Network in Multistory Buildings for Mechanical and Assembly Shops

Width of building B in meters	18	19	20
Width of end aisles L in meters	7.5	8	8
Width of middle aisle l in meters	3	3	4
Spacing of columns t in meters	5	5	5
Height of one story from floor to ceiling h_1 in meters	4.0 - 4.5 - 5.0 - 5.5		
Height of one story of building from floor of one story to floor of other h in meters	4.5 - 5.0 - 5.5 - 6.0		

utilized, but the annexes spoil somewhat the exterior appearance of the building; in the second case the exterior appearance of the building remains unchanged, but the

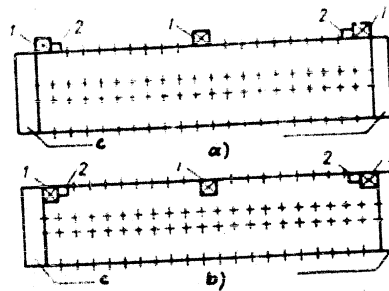


Fig. 17a - Scheme of Location of Stair Wells in Multistory Industrial Buildings
a) Exterior Location; b) Interior Location. 1) Stair well; 2) Freight elevator.

c) Living quarters

internal area is smaller. The toilets, cleaning facilities and relaxation rooms are located at the stair wells.

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The living quarters are located at the ends of the building in annexes, whose height is usually 2.8 meters from floor to ceiling. If, however, the possibility of lengthening the building for expanding the production is contemplated, then the height of the living quarters must be the same as that of the story in which they are located. Living quarters must be provided in each story at each end of the building.

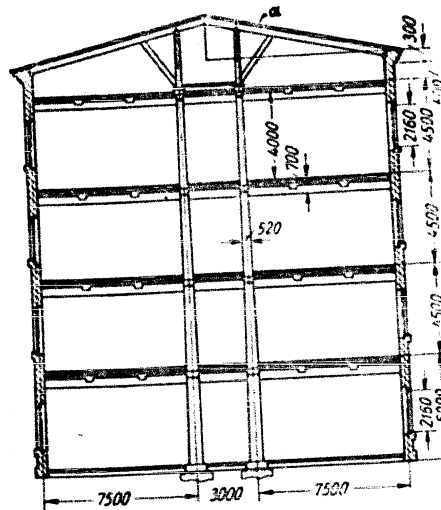


Fig. 175 - Cross Section of Four-Story Industrial-Building

a) Pitch 1:4

In Fig. 175 the cross section of a four-story industrial-building with indication of the principal dimensions is represented.

112. Fundamental Information on Structural Elements

Building Materials

Among the most widely used building materials are wood, stone, mortar, concrete, reinforced concrete.

Wood is widely used for buildings; it is easy to work, has a comparatively small

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coefficient of heat-conduction, a good resistance to stressing; however, it easily burns, rots, dries out, swells, warps; the mechanical strength of wood is different with and against the grain.

Despite these negative particularities, wood, because of its many positive qualities and the possibilities of its use for various building constructions, is widely favored for building. Of the various woods, the most widely used are pine, fir and to a certain extent, oak.

For lengthening the service life of wood products and protecting them against the action of microorganisms, fungi, insects, the wood is subjected to drying, painting, coating and impregnation with antiseptics (aqueous solution of sodium fluoride, creosote oil, etc.).

The drying of wood is natural and artificial. The wood is exposed to drying under the action of the air for 0.5-1.5 years, and with a moisture content of not more than 18% it is suitable for building purposes.

Artificial drying of wood is carried out in drying chambers by means of hot air or with the help of special means with steam heating; it enables the moisture content of the wood to be reduced to 10-12% in a shorter time (several days).

The fire hazard of the wood is reduced with the help of fire-protective measures: use of protective coverings (plaster on felt, asbestos sheets, roofing iron on felt, asbestos-veneer, etc.), or by use of fire-resistant paints.

Building materials are: round timber - saw logs, small rounds, lowgrade lumber (rolls), rods, sawn lumber (sawn material) - building blocks, plates, ties, boards.

Stone materials are natural and artificial. Among the natural materials are: granite, limestone, lime; limestone is divided into crystalline (marble), dense (quarry stone) and porous (tuff). Also included here are the brittle mineral materials: gravel, sand, clay.

Artificial stone materials may be: burned, hardened in the air or in the filling kettle. Burned stones include: bricks - solid, hollow, wedge. Burned bricks

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are red (from clay), porous, wedge-shaped, refractory, etc. Unburned stones are: silicates bricks (from lime and sand), thermoconcrete stones (hollow or solid) air (adobe bricks).

The following mortars are used: lime mortar for stone laying and for plaster; cement mortar for structures requiring great strength. Mixed cement-lime mortar has great strength, is more economical than cement mortar; it is widely used in building; alabaster mortar is used when quick setting is necessary, lime-alabaster mortar is used for plastering on wood; clay mortar serves for boiler masonry, lining furnaces, flues; hot mortar is used for lowering the heat-conduction in masonry joints; they contain, instead of sand (as also takes place with ordinary mortars), ground slag - from coal, peat, etc.

Concrete is an artificial stone material; because of a number of positive characteristics it finds particularly wide use in building construction. Concrete enables nearly complete mechanization of the processes of its preparation and application in carrying on building work, gives the possibility of making from it, in special factories, individual structural elements (beams, columns, plates, etc.), arrives at the building site in ready form, enables variation of the mechanical and heat-protective characteristics of individual structural elements. For making concrete, production wastes (slag) and local raw materials can be used.

Concrete has the following components: binder, water, filler.

As binder, the following are used: Portland cement, slag-Portland cement, pozzuolana-Portland cement, etc.

Water (sweet, tap) serves for making the mix. The ratio of water to that of the binder is called the water-cement ratio.

The following may be used as filler: sand, gravel, stone or brick rubble. A good sand is composed of a uniform mixture of small- and large-grained particles (0.15-5.0 mm). The gravel, stone or brick rubble is first washed with water and sifted through a mechanical sieve for obtaining particle sizes of 5-80 mm.

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Concrete, depending on its composition, has various characteristics of strength, heat-conduction, durability, etc.; on the basis of the requirements which the concrete must fulfill, certain ratios between its components are taken.

The compressive strength is characterized by the mark of the concrete, which shows the mechanical strength (determined in the laboratory) of a concrete tube of age 30 days. The control age for quick-hardening concretes is taken sooner (up to 7 days). Most frequently used for building concretes are marks 110, 110, 170, 200, and 250 kg/square meter; for foundations and floors 90, 110; for preparation below them 50, 70 kg/square meter.

The concrete marks are tentatively denoted $R_{30} = 110$ kg/square meter; $R_{30} = 170$ kg/square meter, etc. where R is the temporal resistance to compression, and the index 30 is the number of days of the age of the concrete cube.

The composition of a concrete is denoted in the form of the gravimetric, or, more rarely, of the volumetric ratio between the quantities of cement, sand and rubble (gravel), at which the quantity of cement is taken as unity; the cement is always proportioned by weight and the sand and rubble by volume. The composition of the concrete may also be given in the form of the expenditures of its individual components by weight per cubic meter finished concrete. Gravimetric proportioning per cubic meter concrete is the better method of denoting the composition of the concrete.

Because ordinary concrete (cold) possesses a considerable thermoconductivity, when it is necessary to have a smaller thermoconductivity, "hot" concrete is used, in which the filler consists of inorganic (slag, pumice, etc.) and organic (peat, sawdust, charcoal, etc.) materials.

Hollow or solid blocks of various weights (from 20 kg to 3 tons) are made from hot concrete.

Reinforced concrete consists of a concrete mass with steel reinforcement consisting of rods connected together by annealed wire. In this way a monolithic iron-

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concrete construction is formed, in which the binding strength between the steel and the concrete reaches very high magnitudes. The strength of constructions of reinforced concrete is considerably greater than that of constructions of concrete alone. Reinforced-concrete constructions are able to resist impacts while concrete alone has a poor resistance to such forces. The reinforcement is made of iron rods (steel). From reinforced concretes, beams, columns, joists, plates, etc, are made.

Besides monolithic, assembled reinforced-concrete constructions are also widely used in building construction. The production of the individual elements of such constructions takes place in special factories using modern methods assuring high strength and density of the reinforced concrete. The building is assembled from ready structural elements delivered to the building site. In assembly, the iron projecting from the beams is welded or tied, the joints are filled up with concrete or mortar made with high-quality cement.

Sites of Buildings and Structures

For preventing unequal settling of buildings and structures they must be built on sufficiently strong ground. The layer of ground sustaining the weight of the whole building or structure is called its site.

Permissible Pressure in kg/square Centimeter of Grounds of Sites at a Depth of the Bottom of the Foundation of 2 meters below the Surface

	kg/cm ²
rock	8-50
gravel	3-8 "
dry clay	2.5-5 "
moist clay	1.5-2 "
wet clay	1 "
medium and coarse sand	2-4 "
fine and dry sand	2.0 "
wet dense sand	1.0-1.5 "
pumped sand	0.5 "
meadow land	0.25-0.5 "

The ground water usually lowers the carrying ability of the ground.

According to their structure the grounds are divided into rocky, sandy, muddy,

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forest, meadow, filled and mixed.

Muddy, meadow or filled grounds cannot serve as a reliable site. The remaining grounds can serve as sites only if the thickness of their layer is not less than 2.0 meters.

Foundations of Buildings

The underground part of the building transmitting the load from the overground part to the site is called the foundation.

The surface of the foundation directly transmitting the load to the site is called the bottom of the foundation.

For preventing unequal settling of the building, the depth of the foundation below the exterior walls must be taken by dependence on the moisture content of the ground, the ground-water level, and the calculated depth of freezing of the ground. The depth of the foundation in clay ground, for taking into account its characteristics in the frozen state, is taken at 20-25 cm below the frost line.

The foundation below the carrying walls of stone buildings is usually made in belts. The width of the foundation below the base (reckoning with 6-12 cm from each side and a base ledge of 5 cm) is taken 17-29 cm greater than the thickness of the wall. The width of the bottom must also be greater depending on the height of the building and the material of the foundation, because various materials possess the ability to transmit the pressure of the underlying layer at a certain angle.

The foundation below the columns is made in the form of individual vertical pillars of steeped form of rubble, rubble-concrete, concrete or reinforced concrete. If the columns are made of stronger material than the foundation, then, for distributing the pressure from the column over the largest area thereof, a subcolumn is provided.

The area of the bottom of the foundation, determined by calculation, depends on the load on the columns and the permissible pressure on the ground. For normal

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grounds the permissible pressure is taken at 2 kg/square centimeter.

With the foundations below the columns of crane spans, the bottom has the form of a rectangle of 1:1.5 to 1:1.8.

Table 57

Orienting Dimensions of Foundations Below Reinforced-Concrete or Brick Columns

Material of Foundation	a	a/h	b in cm	k × k in cm
Bubble	63°	1:2	not less than 40	} not less than 60 × 60
Concrete	56°	1:5	not less than 40	
Reinforced concrete	45°	1:1	30-40	

Some orienting dimensions of foundations below columns (reinforced-concrete or brick) are presented in Table 57, in which the denotations are according to Fig. 176.

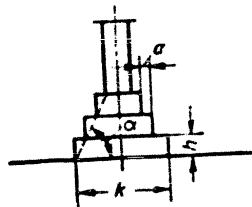


Fig. 176 - Dimensions of Foundation Below Column

Foundations under Metal-Cutting Machines

Metal-cutting machines may be placed in the shop: (a) directly on a floor of suitable construction; (b) on individual foundations or foundations common to several machine tools.

Directly on the floor light and medium machines tools of general purpose operating smoothly and quietly may be placed; from which a high precision of the work is not required, possessing a sufficiently strong base; machine tools having a weight

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up to 7 tons are placed on a concrete floor, machine tools of weight up to 2 tons on a floor of paving blocks, at an over-all size of the machine tools in plan up to 2 square meters. Directly on the floor machine tools with an alternating, reciprocating motion of the working organs (gear-shaping, slotting, planing machines) may also be placed, but only if the shocks and vibrations taking place at their operation do not influence the operation of other machine tools. All of the remaining machines are placed on individual foundations or foundations common to several machine tools.

For placing machine tools on the floor the latter must be of a suitable construction; for this purpose a concrete floor of 150-200 mm thickness (with a sand or slag underlayer of the same thickness) can be used; other possibilities are brick of 120 mm thickness (with an underlayer in the form of a compacted layer of sand or gravel of 150 mm), paving blocks of 60-100 mm thickness (with a concrete underlayer of 100 mm thickness). The floors of the described constructions may be continuous for the whole shop, or in the form of individual segments, or in the form of strips. The machine tools may be placed with fastening thereof on the foundation with bolts, and without an underpouring of cement, so that they can be easily and quickly moved, which is very important for the revision of technological processes. A cement underpouring (thickness 0.5-1.5 cm) is sometimes made for the purpose of obtaining a uniform distribution of the pressure over a larger area of the floor and securing the position of the machine tool on the floor.

Individual foundations for metal-cutting machines are provided for obtaining uniform distribution over the ground of dynamic stresses, and for preventing vibration of the base, which is adversely manifested on the operation of the machine tools, in which the vibrations unavoidably spread to the surrounding area and neighboring equipments.

For providing individual foundations under machine tools, brick, natural stone, rubble, concrete, rubble-concrete, reinforced concrete, or wood are used.

An individual foundation must have the form and dimensions (in plan) corres-

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ponding to the supporting surface of the base of the machine tool.

The depth of the foundation and the size of the area of the bottom thereof, depend on the quality of the ground, the character of the forces acting at the operation of the machine tool, and the requirements of the machine tool with respect to precision. The dimensions of the foundation are usually determined by constructional and technological considerations, sometimes by calculation.

The height the foundation may be taken approximately: for machine tools of weight up to 10 tons at 0.6 meter, for machine tools of weight 10-12 tons at 1.0 meter, for heavier machine tools at 1.5-2 meters.

If the foundation is made in the form of a solid block (when the machine tool is not fastened to the foundation with bolts) its height may be taken at approximately 0.2-0.3 of the smallest dimension of the foundation in plan.



Fig.177 - Clearance between Neighboring Foundations

The clearance between two neighboring foundations depends on their depth. For large equipments, this clearance must be 1.5-2 times the difference between their depths (Fig.177), i.e.:

$$a = (1.5 - 2)h.$$

(268)

The foundation underlayer in the form of a concrete sheet is given a thickness of 300-400 mm, and in the form of a concrete ribbon a thickness of 150-700 mm.

The foundations under the equipments must not be connected with the foundation of the building.

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Floors

According to the sanitary standards, the floors of production rooms must have a level, easily cleaned surface; at working places of light work or work not requiring constant movement, the floor may be heated.

For mechanical, assembly, tool shops and the like, it is convenient to have the floor of wood blocks on a concrete underlayer. A wood-block floor is easy to maintain, does not hinder relocation of machine tools, insulates well from the concrete underlayer, and makes a good road for electric trucks. Elements and tools are not injured by falling on wood blocks. The blocks are usually hexagonal, and the joints between the blocks are filled up with mastic; the height of the blocks is 60, 80 and 100 mm, and the width of the edges is 50-100 mm. The concrete underlayer below the blocks is of 100 mm thickness or somewhat greater.

An uncovered concrete floor (without a floor covering) possesses a great thermoconductivity, so that a board covering should be provided under the machine tools and workbenches. Such a floor hinders movement of transports and walking, and contributes to dirt about the floor. For these reasons, uncovered concrete floors are unsuitable for mechanical and assembly shops, and are rarely used (the thicknesses of the concrete layer and the underlayer are reported above).

For the corridors in shops, brick or asphalt paving is sometimes provided.

In product rooms, floors of ceramic slabs and marble rubble are also used.

In forge shops, floors of various kinds, depending on the character of the production process, are used: floors of stone blocks (for the forge-press, hammer, furnace departments), of brick (for the crank-press and pickling departments), of clinker or concrete (for the heat-treating department), of wood blocks (for the die and tool storerooms).

Walls

In building terminology, walls are divided into carrying walls and shell walls.

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Exterior carrying walls are made of red or silicate brick or of natural or concrete stone. Their carrying and enclosing functions have not been standardized. The thickness of the wall is taken for climate zone I (northern strip) at 2.5 bricks (64 cm); for zone II (middlestrip) at 2 bricks (51 cm) laid in "hot" mortar; for zone III (southern strip) at 1.5 bricks (38 cm).

For increasing the stability of the carrying walls, they are reinforced with pilasters, on which the undercrane tracks for cranes of small loading capacity (Fig.178) are sometimes laid. Pilasters are obligatory if the ratio of the thickness (smallest) to the height of the wall is less than 1:10.



Fig.178 - Pilaster

Shell walls are made preferably of reinforced-concrete or steel and various building materials; with these walls the carrying function is fulfilled by the frame (columns of reinforced concrete or steel) and the enclosing function by the wall filling (of various building materials - red or silicate brick, hot-concrete, stone, porous limestone, etc.).

The location of the wall filling relative to the columns is shown in Fig.179.

The dimensions of the columns are determined by calculation. For assuring the necessary rigidity the cross section ($a \times a$) of the columns must be:

(1) For columns not carrying a crane load, with wood joists $a = H/20$; with metal and reinforced-concrete joists $a = H/25$, where H is the height of the column in cm from the top of the foundation to the top of the bracket on which the joist construction is supported;

(2) For columns carrying the crane load, the greater dimension of the section

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of the column at a crane loading capacity up to 10 tons is not less than $a_b = H_m/11$, and at a crane loading capacity greater than 10 tons not less than $a_b = H_m/10$; the smaller dimension of the section of the column, regardless of the joist construction and the loading capacity of the cranes, must be not less than $a_b = H_m/25$, where H_m is the lower part of the column from the top of the foundation to the top of the monolithic reinforced-concrete undercrane beam or to the top of the bracket on which the undercrane beam is supported.

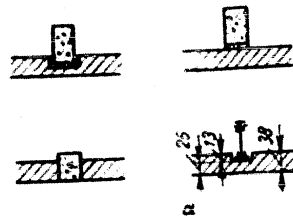


Fig.179 - Location of Wall Filling Relative to Column

a) Dimensions in cm

In all cases the section of a reinforced-concrete column must be not less than 30×30 cm.

Doors and Gates

The distance from the most-remote working-place to the exit to the exterior or to the stairway in an industrial building must not be greater than the norms listed in Table 58 (NSP 102-51).

The greatest distance from the door of the auxiliary (toilet, washing, smoking, relaxation) rooms to the nearest exit to the exterior or stair well must be not greater than listed in Table 59.

The sum of the widths of the doors (and also the sum of the widths of the stairways) of industrial, auxiliary, residence and public buildings on the path of

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evacuation must be taken in dependence on the number of persons present in the most-densely occupied story plus the first story, as follows:

For two-story buildings, 125 persons per meter width of doors (or steps);

For three-story buildings, 100 persons per meter width of doors (or steps);

For buildings higher than three stories, 80 persons per meter width of doors (or steps).

The number of evacuation exits from industrial and public buildings or rooms, must be not less than two; it is permissible to provide one exit from rooms of industry category C of area up to 100 square meters and of industry categories D and E of area up to 200 square meters (on industry categories compare below in this Chapter).

The doors intended for evacuation must open toward the exit from the building.

Table 58

Greatest Distance from Most-Remote Working-Place to Exit to Exterior or to Stairway in Industrial Buildings of Industry Categories C, D and E (NSP 102-51)

Industry Category	Degree of Fire-Resistance of Building	Greatest Distance in Meters	
		One-Story Buildings	Multistory Buildings
C	I	75	50
	II	75	50
	III	60	40
	IV	50	30
	V	50	—
D	I & II	not standardized	
	III	60	—
	IV & V	50	—
E	I & II	not standardized	
	III	100	75
	IV	60	50
	V	50	40

The width of one-sided doors must be not less than 0.9 meter; the width of each of the wings of two-sided doors must be not less than 0.7 meter; the height of the

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doors is 2.0-2.3 meters.

Gates are provided in shop buildings for the transport of materials, products, equipments or parts thereof. The dimensions of the gates are determined on the basis of the over-all dimensions of the used transport means - electric trucks, automobiles, tractors with trailers, cars, electric locomotives, motor locomotives, steam locomotives; with railroad transport, the over-all dimensions of the parts of the structures or equipments close to the railroad track (OST VKS 64345 for 1524-mm gauge and OST 10167-39 for 750-mm gauge with locomotive traction), must be observed.

Table 59

Greatest Distance from Door of Auxiliary Room of Industrial Buildings to Nearest Exit to Exterior of Industry Categories C, D and E (NSP 102-51)

Degree of Fire-Resistance of Building	Greatest Distance to Exit in Meters	
	For Rooms Located Between Stair Wells or Exits to Exterior	For Rooms with Exit into Blind Corridor
I & II	50	20
III	30	15
IV	25	12
V	20	10

In most cases (with the exception of automobiles and railroad cars, a gate width of 2.5 meters at a height of 2.5 meters is amply sufficient. For passage of automobiles, the gate must have a width of 3 meters and a height of 3 meters; for the passage of wide-gauge (1524 mm) railroad-cars the width of the gate is 4 and the height 4.8 meters; when a gateway with gates is provided for these cars, the width of the gateway must be 4.6 and the height 5.5 meters.

Vestibules

For protecting the working places of heated production rooms in regions with a calculated exterior temperature of -20° and lower at permanently and intermittently open gates and doors it is necessary to provide heated openings with the help of

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vestibules, air curtains, etc. (NSP 101-51).

Vestibules for passage of persons are made with two doors, separated from each other by the width of the distance between them plus 0.2 meter, but not less than 1.2 meters; the doors of the vestibule must open outwardly.

The depth of a vestibule for the passage of transport is taken on the basis of the length of the used transport means (electric truck, automobile, railroad car) plus the width of the swing of the door or gate plus 1 meter. The depth of the vestibule need not be greater than 6 meters.

The width of the vestibule is taken as follows:

- (1) The width of the door opening plus 0.6 meter if the vestibule is intended only for the passage of persons;
- (2) The over-all width of the loaded truck or car plus 0.6 meter on each side if the vestibule is intended for the passage of transport;
- (3) The over-all width of the loaded car or truck plus 0.6 meter on the one side and on the other the width of the passageway calculated according to the norms of passability.

The vestibule must be lighted by natural light.

Stairways

The stairways are located in stair wells. The materials of the stairways and stair wells are selected corresponding with the degree of fire-resistance of the building. The stair wells must have natural lighting.

The permissible distances from the most-remote working-place or door of auxiliary rooms to the nearest exit to the exterior are established in the norms of building planning (NSP 102-51), reproduced in Tables 58 and 59.

The width of the steps of a stairway serving for evacuation must be not less than 1.2 or greater than 2.2 meters.

The sums of the widths of the stairway steps, as well as of the doors, taken

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according to the established norms depending on the number of persons present in the most-densely occupied story of the building, have been reported above. In the same place, the number of exits from the rooms are also given.

The ratio of the depth of the stairway to the rise is taken not less than 1.5, but more frequently 1.75-2. In each stairway, not less than 5 and not more than 18 steps are provided. The most convenient are steps of 15×30 cm and 16.5×39 cm (height and width of step).

Partitions

Various forms of interior partitions are used in industrial buildings depending on the purpose of the rooms. They are:

- (a) of plastered wood;
- (b) of glass with lower part of wood;
- (c) of wire-netting with lower part of wood;
- (d) metal-reinforced glass;
- (e) of brick;
- (f) of reinforced concrete;

Storerooms are separated by wire-netting partitions with the lower part of wood of height 1 meter and total height 2.5-3.0 meters.

For the sharpening, grinding, gauging departments, particularly precision machine tools, etc., glass partitions with the lower part of wood of height 1 meter and total height 2.5-3.0 meters are provided.

For the metal-coating, painting, heat-treating departments, etc., in which harmful gases and vapors are liberated, or in which the production is fire-hazardous, brick partitions of thickness 1-1.5 bricks or reinforced-concrete partitions of thickness 300 mm are provided.

Plastered-wood partitions are used in service rooms - living, office, etc.

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Skylights

Skylights are provided for lighting multi-aisle industrial buildings with daylight; they serve, at the same time, for natural ventilation (aeration). The skylights may be located along the ridge of the roof (longitudinal skylights) or perpendicular thereto (transverse skylights). At the present time, longitudinal skylights are mostly used. Transverse skylights give unequal illumination in the direction of the technological flow; moreover, they are difficult to apply to buildings with different heights of its individual parts.

The forms of skylights are triangular, sawtooth, trapezoidal, rectangular and M-form (Fig.180).

Triangular skylights (Fig.180a) have the glazing at an angle of 45° ; they are made only dead, i.e., cannot be opened, because the slope of the glazing makes it impossible to assure water-impermeability; such skylights are rarely used today, and only for small buildings; the width of triangular skylights is usually not greater than 3 meters.

Sawtooth skylights, having a vertical (Fig.180c) or an inclined (Fig.180b) glazed surface turned toward the north or northeast, are adopted when direct sun rays must not penetrate into the room. In localities with heavy snowfall, such skylights are not used because of the formation of a snow blanket covering the glaze.

Trapezoidal skylights (Fig.180d), having their glazing at an angle of 60° to the horizontal, gives a sufficient illumination of the room, but inclined glazing is dirtied more than vertical, and snow is retained on it; because of this, and also because of its complicated construction, skylights of rectangular (Fig.180e,f,h,i,j) and of M-form (Fig.180g,k), are preferred.

Rectangular skylights have vertical glazing, which dirties less, and at which there is a smaller penetration of direct sun rays into the room; the construction of these skylights is simpler than that of the trapezoidal skylights; the rectangular skylights are the most widely used in modern industrial buildings.

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For the buildings of hot-working shops, where there is a considerable liberation of heat and harmful gases, skylights of M-form are used, while the inclination of the

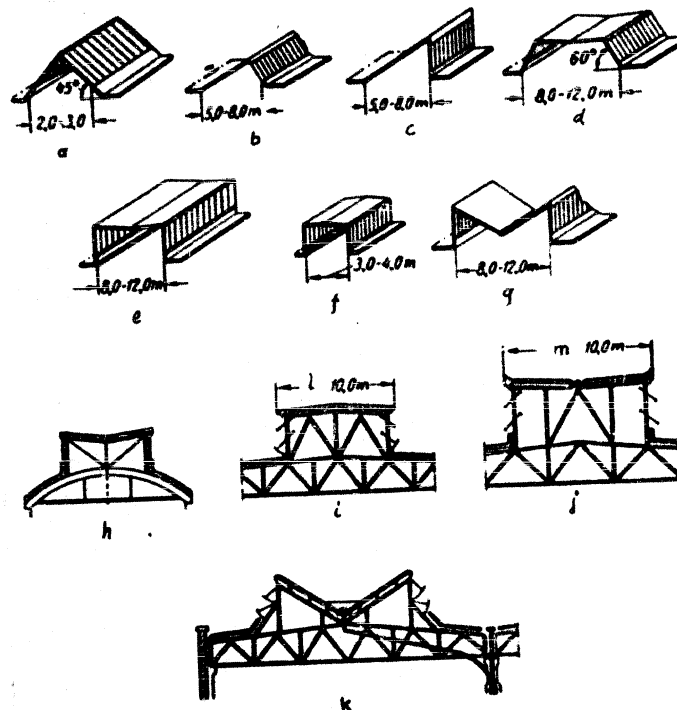


Fig. 180 - Forms of Skylights

- a) Triangular; b,c) Sawtooth; d) Trapezoidal; e,f) Rectangular; g) M-form with vertical glazing; h) M-form at reinforced-concrete construction, skylight combined with water-drainage system; i) Internal water drainage; j,k) Internal water drainage; l) Up to 10 meters; m) Greater than 10 meters.

surface directs the air currents from the inner side to the hinge of the glazing.

In Fig. 180i,j,k, the locations of the hinges and the schemes of external and

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internal water drainage with the skylights, are shown.

The skylights of industrial buildings are provided with ordinary glazing.

The casements of skylights are made in one, two or three tiers; in each tier the casement is opened with a separate hinge or the whole tier.

The opening of the skylight takes place from below, at the floor level, with the help of a special mechanism or by hand by means of a chain running over pulleys, or by means of an electric motor. For opening and closing long ribbons of glazing, electric motors are used.

The cleaning of the inner surface of the glazing of the skylight takes place from a special truck running along the skylight on a track mounted on the upper face of the girder.

Tentative Denotation of Structural Elements

In view of the large number of structural elements depicted on the plans of industrial buildings, it is desirable to give it a tentative denotation. Such a tentative denotation is presented in Fig.181.

113. Fire-Protective Measures with Industrial Buildings

With respect to fire hazard industrial enterprises are divided into five classes: A, B, C, D and E.

Class A includes chemical manufacture connected with the production, treatment or use of gaseous substances, readily-inflammable liquids and similar productions; this class also includes hydrogen and acetylene units.

Class B includes manufacture connected with the production and transportation of particles of spontaneously or readily inflammable solids in the air and other productions.

Machine-building works have no manufacture belonging directly to classes A

and B.

The industry classes C, D and E include, among many other industries (textile,

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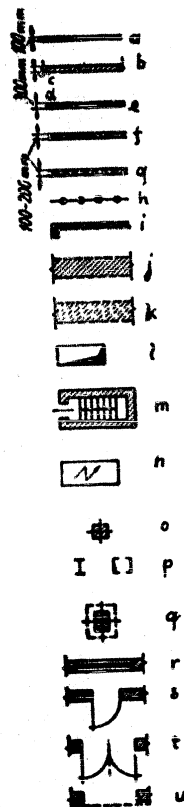


Fig. 181 - Tentative Denotation of
Structural Elements

- a) Plastered-wood partition;
- b) Brick partition;
- c) In thickness 1 brick-250 mm;
- d) In thickness 1.5 bricks-380 mm;
- e) Reinforced-concrete partition;
- f) Glass partition with lower part of wood;
- g) Glass partition with lower part of wood;
- h) Barrier;
- i) Sound-insulating partition;
- j) Cellar, underground, pit;
- k) Mezzanine;
- l) Manhole;
- m) Stair well;
- n) Shop transformer box;
- o) Brick pillar;
- p) Metal column;
- q) Reinforced-concrete column and its foundation;
- r) Window;
- s) One-wing door;
- t) Two-wing door or gate;
- u) Sliding door or gate.

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sewing-machine, paper, typewriter, etc.), the following shops of machine-building works:

Class C: sawmill, woodworking, planing, patternmaking, wood-packing, lubricating-oil regeneration, transformer.

Class D: foundry, forge, heat-treating, hot rolling of metals, steam and electric-locomotive depots, motor-testing stations, boilerhouses, internal-combustion-engine rooms, machine halls of power stations.

Class E: mechanical (cold treatment of metals), tool, cold stamping and rolling of metals, stock (scrap) yard, electric-locomotive and truck depots, air and compressor stations, pumping stations for incombustible liquids.

The construction of buildings or structures, with respect to fire resistance, is subdivided into five classes: I, II, III, IV, and V.

Buildings of class I and II have all parts of the building incombustible; buildings of class III have parts of the building incombustible (ground floor), difficultly-combustible (interstory and attic floors, partitions) and combustible (nonattic roof), and incombustible (firewalls); buildings of class V have parts of the building combustible and incombustible (firewalls).

The incombustible parts of buildings are those constructed of incombustible materials.

The difficultly-combustible parts of buildings include those constructed of difficultly-combustible materials or of combustible materials protected against fire by incombustible plastering and facing materials.

The combustible parts of buildings include those constructed of combustible materials and not protected against fire by incombustible plastering or facing materials.

The required degree of fire resistance of the buildings, in accordance with their number of stories and the classes of fire-hazard manufacture housed in them, and also the floor area of each story bounded by firewalls (compare below in this

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Chapter), which must be taken in accordance with the standards of building planning of industrial enterprises (NSP 102-51), for manufacture of groups C, D, and E, are presented in Table 60.

Table 60

Degree of Fire Resistance and Greatest Permissible Area Between Firewalls
(in square meters) For Industry Categories C, D and E

Industry Category	Greatest Permissible Number of Stories	Required Degree of Fire Resistance	Greatest Permissible Area Between Firewalls in Square Meters	
			One-Story Buildings	Multistory Buildings
C	not standardized	I	not standardized	
	6	II	7000	4000
	3	III	3000	2000
	1	IV	2000	
	1	V	1200	
D	not standardized	I & II	not standardized	
	2	III	3000	2000
	1	IV	2500	
	1	V	1500	
E	not standardized	I & II	not standardized	
	3	III	4500	3000
	2	IV	3000	2000
	2	V	2000	1250

Remark: The Table only contains the data on the standards for the categories of productions relating to machine-building works

Depending on the degree of fire resistance of the buildings, standards of intervals between buildings, structures, enclosed storages (compare Chapter II, Table 1), are established.

In industrial buildings, fire-protective barriers must be provided; firewalls, fire-protective zones, fire-protective floors and walls, and also evacuation exits (doors and stairways).

Firewalls are defined as blind fire-resistant walls dividing vertically all the parts of the building.

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Firewalls separate: (a) the greatest permissible floor areas of the building; (b) the living quarters from the shops; (c) the more fire-hazardous production, storage and other rooms from the less hazardous; (d) rooms with different degrees of fire-hazard. Firewalls may be either continuous or discontinuous.

The firewalls must extend above the roof, and also above the skylights and other constructions projecting above the roof, not less than 70 cm on combustible roofs and not less than 40 cm on difficultly-combustible roofs. The firewalls must have a clearance from the outer surface of the wall, from the cornice or overhang of the roof of not less than 40 cm.

The doors, gates and filled openings in the firewalls and other fire-protective barriers must be incombustible or difficultly-combustible and have a maximum fire resistance of not less than 1.5 hours.

The greatest permissible floor areas in the buildings, depending on the industry categories, the numbers of stories, the degrees of fire resistance are taken according to the standards presented in Table 60.

In the equipment of the production rooms with sprinklers, the floor areas bounded by firewalls can be increased 50% compared with the areas shown in Table 60.

At storage of different kinds of materials and products in the same warehouse, the space must be divided by firewalls into compartments according to the same kind of extinguishing means (water, foam) and the same kind of combustible materials. The maximum area of the compartment must not be greater than that shown in Table 60.

The firewalls in one-story buildings below fire resistance category II may, on the basis of technological considerations, be replaced with fire-protective zones; on this, the norms of the greatest areas of the horizontal projections of the roof parts bounded by these zones are taken according to Table 60.

A fire-protective zone consists of a strip of fire-resistant roof with a width not less than 6 meters (i.e., corresponding to the spacing of the columns), two reinforced-concrete ridges rising 70 cm above the barrier, and a reinforced-concrete

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apron between the tie arch and its outline. The skylight must not intersect the zone.

In Figs. 182 and 183 some schemes of reinforced-concrete fire-protective zones

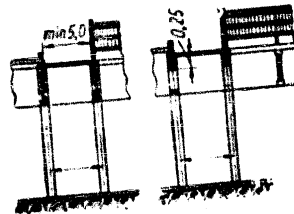


Fig. 182 - Schemes of Reinforced-Concrete Fire-Protective Zones

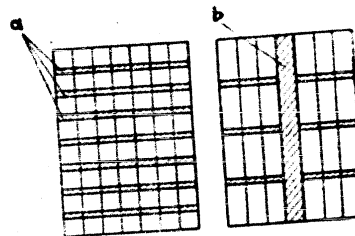


Fig. 183 - Location Plans of Fire-Protective Zones

a) Fire-resistant zones; b) Fire-resistant span

in plan and their location are shown.

Fire-resistant floors separating production rooms, archives and kitchens in auxiliary buildings or in annexed living quarters of fire-resistance degree III

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must be incombustible. In buildings of fire-resistance degree V the floors and walls of such rooms must be difficultly-combustible.

The floors and walls of corridors in industrial buildings of fire-resistance degrees I-IV, located above corridors of production or auxiliary rooms, must be made of incombustible materials.

In industrial buildings and storages, the distance between the fire stairways must be not greater than 200 meters measuring according to the perimeter of the building.

The measures for assuring fire safety, with respect to the provision of exits, doors and stairways, are reported in Section 112 of the present Chapter ("Doors and Gates" and "Stairways").

For fire-protective purposes, lanes and corridors provided in accordance with the manufacturing conditions, must be used. If the provision of such lanes is unnecessary, then access of the fire-engines must be assured over the unbuilt grounds along the whole length of the building on not less than two sides, and approach to buildings covering a ground area of more than 10 hectares, must be assured on all sides.

114. Illumination of Shops and Other Rooms

The natural and artificial illumination in production, administrative-office, living and other rooms, must be planned in accordance with the existing GOST standards.

All production, storage, living and administrative-office rooms must have direct natural illumination.

Substitution of natural by artificial illumination is permitted in toilets, wash rooms, rest rooms, and locker rooms, if mechanical ventilation is available.

In the absence of mechanical ventilation, a substitution of natural by artificial illumination in toilets, wash rooms and rest rooms is permitted at not more than three spots, and, in locker rooms, at not more than 100 spots. Wash rooms, passage-

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ways, and storages may be illuminated by secondary light, i.e., by windows not opening directly on the exterior.

For obtaining natural illumination, windows in the exterior walls and skylights in the roof are provided. Skylights used for ventilation must have openable casements.

The size of the windows and their location is determined depending on the necessary illumination, which must be as uniform as possible. With the provision of windows in production rooms, it is necessary to provide protection against direct sun rays.

The degree of illumination of a production room is determined by the value of the coefficient of natural illumination e of the calculated working surface.

The coefficient of natural illumination e is defined as the percentual ratio of the illumination in a given point of the room to the simultaneously exterior illumination of the horizontal plane illuminated by the diffuse light of the whole sky.

Thus, for example, if the exterior illumination of a given place in a 12-hour day in December equals 3500 lucas and the interior illumination in the same time equals 35 lucas, then the coefficient of illumination equals 1%.

If the production room is illuminated by upper or combined light, i.e., by upper and lateral (through windows), the average value of the coefficient of illumination e_{av} is ascertained. If, however, the room is illuminated by lateral light only, the minimal value of the coefficient of illumination e_{min} is ascertained in the point most remote from the window.

The average values of the coefficient of illumination for some important shops and rooms are presented in Table 61.

In determining the value of the coefficient of illumination, the loss of light due to the panes and sash and to the shadows of equipments and structural elements of the building must be taken into account; the light-climatic particularities of the given locality must also be taken into account.

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There are three systems of artificial illumination:

(a) General illumination, intended for illumination of the entire room as a whole by uniformly or locally-placed lights;

(b) Local illumination, intended for illumination of working places only (stationary and portable);

(c) Combined illumination, intended for combined use of general and local illumination.

The use of local illumination alone is prohibited.

Table 61

Norms of Illumination in Shops and Rooms of Machine-Building Works

(According to GOST 3875-47)

Production	Coefficient of Natural Illumination ϵ			Artificial Illumination; Minimal Illumination in Lucas; General Only
	Upper of Combined	Lateral Only	Local and General	
I. Precise work; mechanical and tool shops	5	1.5	150-300	75-125
II. Assembly sections of mechanical shops; hot-working shops; repair of automobiles and tractors; woodworking shops	3	1.0	75	20-50
III. Rough work or requiring only in general observance; tool storages	2	0.5	—	10
IV. Storages of large objects and loose materials	1	0.3	—	5
V. Work with self-luminescent objects or materials (for example in forge shops and foundries)	3	1.0	—	50

Artificial illumination is divided into: (a) working; (b) emergency.

The working illumination must assure the standard illumination of the working places and auxiliary areas.

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Table 62

Standards of Illumination for Distinguishing Fine Details

With Dimensions up to 10 mm (From GOST 3825-47)

Character of Work	Class of Work	Subclass	Background on which Details are Distinguished	Contrast of Detail with Background	Minimum Illumination in Lux	
					In Systems of Combined Illumination	In Systems of General Illumination Only
Distinguishing details of dimensions smaller than 0.2mm	I	a	dark	small	500	Use of only one general light prohibited 125 75
		b	dark	great		
		c	bright	small great	300 150	
Distinguishing details of 0.2 to 1 mm	II	a	dark	small	300	125
		b	dark	great		
		c	bright	small great	150 —	75 30
Distinguishing details of 1 to 10 mm	III	a	dark	small	75	50
		b	dark	great		
		c	bright	small great	— —	30 20

Remarks: 1. The system of general illumination may be adopted for work of classes Ib, Ic, Ila, IIb, IIIa if the technological conditions make it impossible to provide combined illumination.

2. If intense visual work in working processes characterized by classes and subclasses Ib, Ic, Ila, IIb, IIIa takes place continuously or nearly continuously during the working time, then in the system of general illumination the norms of illumination shown in the Table are doubled, and Remark 3 below does not apply.

3. The norms of illumination listed in the Table for work classes II and III relate to cases when the distance from the eye to the observed object is less than 500 mm. If this distance is greater than 500 mm, the illumination must be selected according to the next higher class.

4. In a system of combined illumination, the illumination at the level of the working surface from the lights of the general illumination must be not less than 10% of the norm listed in the Table but not less than 10 lux; the use of illumination higher than 30 lux is not obligatory.

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The emergency illumination must (on failure of the working illumination) assure the illumination necessary for temporary continuation of the work or for emergency exit of the people from the room.

The standards of artificial illumination are established depending on the character of the work and the purpose of the rooms (compare Tables 61-63).

For determining the yearly consumption of electricity for illumination by expansion calculation, 12-15 watts per hour per square meter floor area of shops is taken, including service rooms and living quarters.

Table 63

Norms of Illumination of Administrative-Office, Public Rooms and Living Quarters, Passageways in Production Rooms, Corridors and Stairways (From GOST 3825-47)

Name of Illuminated Area	Class of Work	Minimum Illumination in System of General Illumination in Lux	Plane to which Illumination Norm Applies
Administration-office rooms	VIII	50	Surface of tables
Rooms for receiving and preparing food	IX	50	Surface of tables
Living, locker, washing relaxation, toilet rooms	X	15	Surface of tables
Main passageways in production rooms, corridors for transport, intra-shop stairways, main corridors and stairways, other passageways, corridors, stair ways, vestibules	XI	10	Surface of floor
	XII	5	Surface of floor

Remark: In administrative-office rooms, supplementary use of local illumination is recommended.

115. Heating, Ventilation and Air-Conditioning

Heating: For works, the most rational systems of air heating and systems of heating with heating appliances (radiators, finned pipes) are generally used.

Systems of air heating are used in large industrial buildings (with a heat loss of more than 80,000 Cal/hr); systems of heating with heating appliances are used in

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small industrial buildings, in administrative-office rooms, living quarters, laboratories, and eating rooms.

In large industrial shops, heating systems of mixed types are sometimes provided, in which the air heating is the main one but along the walls of the building supplementary heating appliances for protecting the working places against currents of cold air are further provided.

Air heating can be provided by one of two methods: (a) direct heating of inflowing air; (b) with concentrated feed of air.

The first method of realizing air heating is the simplest and most economical. In buildings with a ventilation inflow system, the piping and air ducts of the inflow ventilation can be used if the air output of this system corresponds to the necessary air volume in air heating, otherwise the air heating is formulated independently of the system of inflow ventilation.

The action of the system of air heating with concentrated feed of air consists essentially in feeding heated air to several points of the building; with this system a uniform temperature distribution in the rooms is obtained both horizontally and vertically.

Such systems of air heating are advantageously used in buildings of large volume in which mechanical, assembly and tool shops with little unoccupied space are located.

For systems of heating with heating appliances, the following are used as heat carriers:

Superheated water or steam at high pressure (4-5 atm) - for production and storage rooms;

Superheated water - for laboratories and administrative-office rooms;

Superheated water or steam - for living quarters.

As heating appliances, the following are used: finned pipes - for production and living quarters, garages and the like rooms; radiators - for laboratories,

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administrative-office rooms, eating rooms, etc.

The economy of any heating system may be determined in a considerable degree by the extent to which the temperature parameters of the heat carrier are fully utilized.

Ventilation: For obtaining the most rational and economical decision of the question of ventilation of production rooms, it is necessary to take technological, constructive and structural measures with regard to the equipments and structures which assure the smallest liberation or the neutralization of the contaminants taking place in the production process, the smallest penetration of them into the rooms. Such measures include: improvement of the technological process; hermetic sealing and insulation of production equipments liberating contaminants; wet treatment of materials local removal (in grinding, sharpening, woodworking machines, in furnaces, baths, crushers, etc.).

If such measures are unable to assure the normal condition of the air in the room, then the liberated contaminants must be removed with the help of a ventilating system.

The ventilation may be natural or mechanical.

Organized natural ventilation (aeration) takes place by opening the skylights, windows, through which the air enters and departs under the action of internal and external factors, such as: the exterior and interior temperature, the pressure and velocity of the wind.

For creating the optimal conditions of aeration there is considerable importance to the proper planning of the shop departments inside the building, the form of the building, the most rational construction of the skylights, their location, and the window openings.

Mechanical ventilation may be outflow, inflowing, inflowing-outflowing (combined).

Outflow ventilation serves to remove the contaminants in the place of their

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formation (chemical laboratories, smoking rooms, toilet rooms) with the help of fans (electromechanical); the arrival of fresh air proceeds naturally.

At inflow ventilation fresh (exterior) air is pressed into the room by fans; the interior air departs naturally through exit holes; inflow ventilation is used when it is necessary to create back pressure for protecting a room from penetration of foul or cold air from neighboring rooms.

The inflow-outflow system takes care of both the mechanical supply of air and the mechanical exhaustion. This system is the most rational for assuring the necessary change of air.

With this system the exterior air sucked in by the fan is directed into the inflow chamber, where it passes along a heating apparatus; further, via the inflow flue, it arrives in the air ducts of the room. The foul air is, with the help of electric exhaust fans, directed to the exhaust chamber via collecting flues - air ducts located on columns of the building or below the ceiling.

Air Conditioning in Shops: This term is defined as the creation (in production rooms and laboratories, regardless of the exterior meteorological conditions) of a particular temperature and humidity of the air, corresponding to the requirements of the technological process.

The air-conditioning system must assure the cooling and drying of the air arriving in the room in summer, and its humidification and heating in winter.

In machine-building works, air conditioning is provided in technical-measurement laboratories, in rooms in which the final treatment and assembly of high-precision products is carried out (precision antifriction bearings, precision apparatuses, instruments) and in other rooms where a constant temperature is required.

For decreasing the influence of solar radiation in such rooms, the light openings should be located on the north side, and it is best not to use skylights. The windows should be covered with whitewash, shades, shutters, etc.

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For calculation, the interior temperature of the rooms of a machine-building works with air conditioning is taken at $+20^{\circ}$.

For the air-conditioning system, a cooling machine working with a cooling agent is used - ammonia or freon.

An ammonia cooling machine must be housed in a special insulated room.

The scheme of the air feed of the air-conditioning system is "from above downward", i.e., the air intake is in the upper zone of the room and removed from the lower zone.

Air-conditioning systems are equipped with automatic regulating means (thermostats - varying the temperature, humidostats - varying the humidity, regulating valves, etc.).

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CHAPTER XIX

GENERAL COMPONENTS OF SHOPS IN ONE BUILDING

116. Variants of Components

Instead of constructing separate small buildings, it is advantageous from the economic and technical viewpoints to combine the production and auxiliary shops in the form of a block of shops in one building.

The cost of construction per cubic meter of separate small buildings is considerably more than that of one large block combining several shops.

The housing of small shops in individual detached buildings increases the size of the works grounds, lengthens the intraworks travel distances and communication lines, increases the expenses for landscaping and fencing of the grounds, and also the operating expenses. Therefore, whenever the production conditions make it possible, the production and auxiliary shops must be combined in one building, either one-story or multistory.

The formulation of the general components of the shops must be guided by the following fundamental considerations:

1. It is advantageous to combine in the form of a block of shops in one building production shops connected with each other by a common production process, or in which groups of equipments can cooperate for the purpose of their optimal utilization; the auxiliary shops serving them may also be included in the block of shops.
2. All of the components combined in one block of shops must also take into account their location relatively to each other in such a way as to assure the prop-

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er sequence of the processes of treatment and the shortest paths of load flow without return movements.

3. Straight flow of the production process corresponding to the fundamental scheme of machine-building production must be assured.

4. It is necessary to concentrate and locate at the exterior walls the departments and shops liberating foul air (heat-treating, painting, galvanizing, etc.), except when these processes are included in the general flow line, then suitable means must be provided for removing the foul air.

5. It is necessary to adopt as much as possible unified dimensions of aisles - width, length, height.

6. The shop departments should be concentrated in a separate aisle, for which it is necessary to increase the aisle and the crane equipment.

7. It is necessary to locate the line of treatments of the mechanical shop relatively to assembly shop in such a way that the treated elements arrive at the assembly over the shortest path and at the point in the assembly line where they are to be assembled.

8. It is necessary to use in large-series and mass production, specialized departments for aggregates and units of machines with final technological cycles of treatments and assembly of the given aggregates and units; in series and small-series production, specialized technological departments - for mechanical treatment, unit assembly, general assembly; specialized departments of mechanical treatment according to groups of elements - department of body elements, department of shafts, department of gears, etc.

9. At the inclusion in the block of shops of auxiliary shops - tool, repairs, mechanical, experimental (as is often the case with small and medium-sized works) - they should be located in a side aisle, out of the way of the general production flow.

10. In planning of the general components of a block of shops, the possibility

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of combining auxiliary departments, storage and transport means serving similar or identical shops should be considered.

On the basis of the foregoing considerations, it is advantageous to combine in one building the following groups of shops (each group forms a block of shops):

1. Mechanical and assembly shops of various types of machines or aggregates, coating shops - metal and varnish-paint, heat-treating shops, cold-stamping shops, auxiliary departments, storerooms, living quarters.
 2. Mechanical, assembly and other shops of cold treatment making elements or products going into the general assembly of machines; auxiliary departments, storerooms, living quarters.
 3. Mechanical and assembly shops, auxiliary departments, storerooms, living quarters.
 4. Tool, mechanical-repair, electric-repair, experimental, readying shops, auxiliary departments, storerooms, living quarters.
 5. Mechanical, assembly, readying, tool, mechanical-repair, experimental shops, auxiliary departments, storerooms, living quarters.
- Besides the enumerated variants of the components of shops in block, others are also possible depending on the conditions of the production.

117. Examples of Components of Shops

Examples of the components of mechanical and assembly shops with auxiliary departments and storerooms, and also tool, mechanical-repair, foundry and force shops, have been presented in the respective chapters.

Examples of the general components of some shops in one building are shown in Figs. 184-188.

In Fig. 184, a typical scheme of the general components of the mechanical, assembly, tool and mechanical-repair shops with heat-treating, painting, testing departments, shipping, and also storage and living quarters of a machine-building works of series production is presented.

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The mechanical shop occupies five aisles of 12 m width each; the assembly shop is located in a 15m wide aisle perpendicular to the aisles of the mechanical shop.

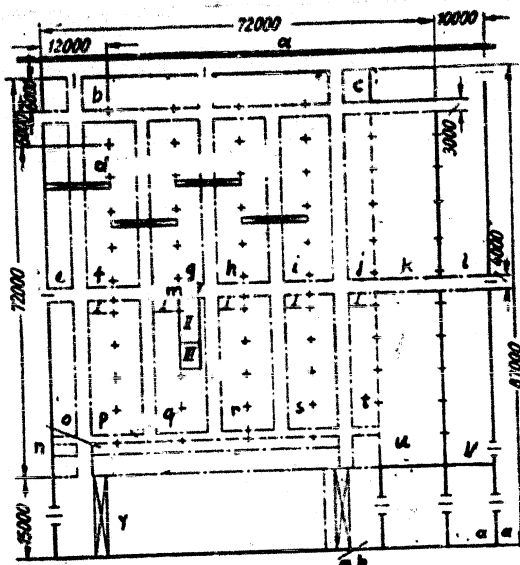


Fig. 184 - Typical Scheme of General Components in One Building of Mechanical, Assembly, Tool and Mechanical-Repair Shops of Machine-Building Works of Series Production

I - Foreman's place; II - Tool distributing storeroom; III - Sharpening department. a) Railroad; b) Shop storage of materials and blanks; c) Heating; d) Mechanical shop; e-j) Machine tools; k) Tool shop; l) Living quarters; m) Passageway; n) Checking department; o-t) Machine tools; u) Mechanical-repair shop; v) Living quarters; w) Passageway; x) Intermediate storage; y) Assembly shop; z) Painting department; aa) Shipping; ab) Testing department

The testing and painting departments are placed in the assembly aisle. The shop storage of materials is located in the beginning of the aisles of the mechanical

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shop. The tool and mechanical-repair shops occupy a separate side aisle.

The living quarters are located on the long side of the building because the railroad track runs along the face side of the shop.

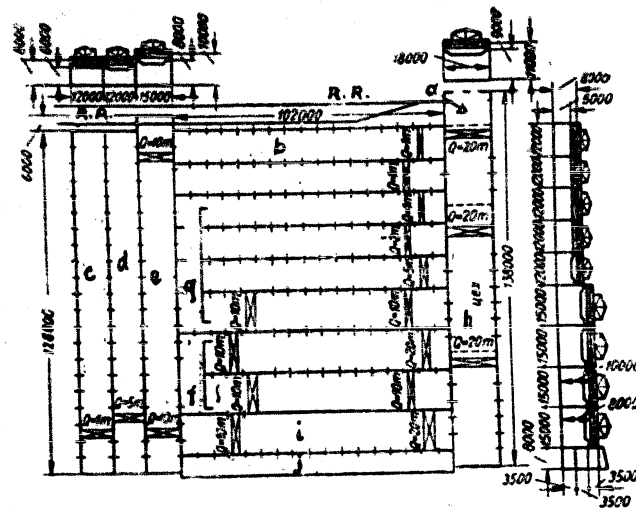


Fig.185 - Plan of General Components in One Building of Mechanical, Assembly and Other Shops of Machine-Building Works

a) Shipping; b) Shop of appurtenances and tooling; c) Tool shop and department of master mechanics; d) Mechanical-repair shop; e) Readyng shop and storage; f) Shop of small-series production; g) Shop of series production; h) Assembly shop; i) Experimental shop; j) Living quarters and office room

In Fig.185, the plan (section) of the general components in one building of the several shops of a machine tool-building shop is presented: mechanical shop, shop of appurtenances and tooling, assembly with painting department and shipping, tool, mechanical-repair, readyng.

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The building consists of ten parallel aisles, occupied by the mechanical shop, shop of appurtenances, experimental shop, located in an aisle perpendicular to the mechanical aisles, and three parallel aisles, also located perpendicular to the mechanical aisles, and occupied by the readying, mechanical-repair and experimental shops.

The living quarters and office rooms are located parallel to the nine parallel aisles. The railroad track enters the storage and the assembly shop.

In Fig. 186, the general components of the mechanical, assembly and other shops for the production of motortrucks are depicted.

The building has seven aisles: four of 18 m width and three of 24 m width with a column spacing of 6 m. The total area of the body (without the living quarters) is 43,802 square meters with a length of 314 and a width of 144 m; height 9.9 and 11 m.

The mechanical and assembly shops consist of departments and sections: treatment of elements of rear dump trucks; treatment of miscellaneous elements; automatic-turret-lathe treatment; treatment and assembly of brakes and compressors; treatment and assembly of front axles; treatment and assembly of rear axles; treatment and assembly of 12-ton machines; checking-delivery; heat-treating; auxiliary rooms, etc. After the enumerated departments, the main conveyor of the general assembly of automobiles is located.

On the other side of the main conveyor, the following departments and sections are located: stamping, assembly and painting of rear dump trucks; stamping of large elements, assembly and painting; mechanical-repair; repair and storage of stampings; stamping of medium-sized elements; stamping of small elements; stamping, assembly and painting of frames and rear axles; radiator-fittings; metal-coating; tapestry.

At the beginning of these departments, the rooms for the storage of metal (with readying section), blanks, wheels, tires, and also the section of waste-briquetting are located.



Fig. 186 - Plant of General Components in One Building of Mechanical, Assembly and Other Shops for Production of Motor-trucks

I - Storage of metal, blanks, wheels, tires, waste, reworking department; II - Department of assembly and painting of rear dump wagons; III - Departments of large stampings, assembly and painting; IV - Department of repair pairs and storage of stampings and room of repair teams; V - Department of medium-sized stampings; VI - Department of small stampings; VII - Department of rear axles; VIII - Radiator-fittings department; IX - Department of metal-coating; X - Basement for storage chambers and tire casings; XI - Main conveyor; XII - Checking department of mechanical treatment of elements rear dump trucks; XIII - Department of automatic turret lathes; XIV - Department of mechanical treatment and assembly of miscellaneous elements; XV - Department of compressors; XVI - Department of mechanical treatment and assembly of brakes and compressors; XVII - Department of rear axles; XIX - Department of mechanical treatment and assembly of front axles; XXIII - Department of mechanical treatment and assembly of 12-ton machines; XXI - Auxiliary room; XXII - Thermal shop of treatment and assembly of briquetted machines; XX - Living quarters; XVI - Central and distributing point of electric energy; XVII - Briquettery; XXIV - Office Room. a) Railroad branch; b) And story; c) 3rd story.

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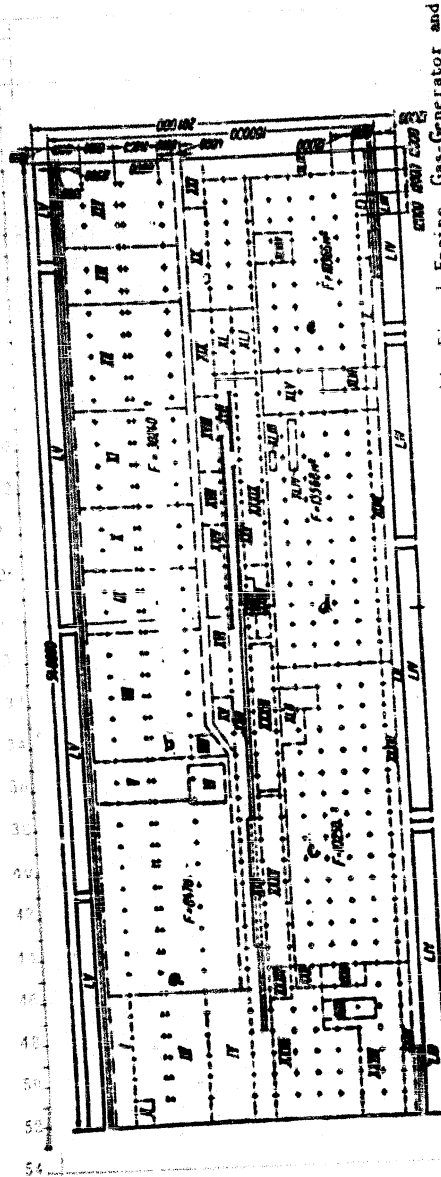


Fig. 189 - Plan of General Components in One Building of Mechanical and Assembly Diesel-Engine, Gas-Generator and

Cold-Stamping Shop; III - Section for eliminating defects, outfitting and delivering trac-

I - Loading platform; II - Washing chamber; III - Section for eliminating defects, outfitting and delivering trac-

tors; IV - Section for polishing tractors; V - Ready department of large sheet stampings; VI - Hydrostation; VII - Radiator-fittings de-

partment; VIII - Radiator-painting section; IX - Department of cold stamping; X - Department of frames; XI - Storage

of air cleaners; XII - Painting section of department of large sheet stampings; XIII - Storage place; XIV - Painting section of

place; XV - Storage place; XVI - Painting section of department of large sheet stampings; XVII - Storage

department of air cleaners and friction disks; XVIII - Phosphating section of department of tractor trucks; XIX - Transporter of tractor trucks;

tor-painting chamber; XX - Main conveyor of general assembly of tractors; XXI - Substation; XXII - Grinding group of cat-

erpillar department; XXIII - Main conveyor of general assembly of tractors; XXIV - Storage of rods on shelves;

of chassis shop; XXV - Heat-treating section of caterpillar department; XXVI - Storage of ready elements; XXVII - Defect

XXVIII - Storage of blanks of diesel-engine department; XXIX - Section of painting of engines; XXX - Defect

assembly of engines; XXXI - Testing station of engines; XXXII - Section of painting of engines; XXXIII - Defect

department of engines; XXXIV - Department of unit assembly of diesel-engine shop; XXXV - Transformer

department of piston rings of normal shop; XXXVI - Heat-treating department of diesel-engine shop;

XL - Heat-treating; XLV - Painting department of chassis shop; XLVI - Painting department of diesel-engine shop;

XLVII - Storage of blanks of chassis shop; XLVIII - Heat-treating shop of normals; XLIX - Painting department for

castings; L - Storage of blanks; LI - Storage of rods; LII - Main corridor; LIII - Railroad track; LIV - Southern

living room; LV - Northern living room. (a) Gas-generator shop; (b) Block-stamping shop; (c) Diesel-engine shop;

(d) Chassis shop; (e) normal shop

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The living quarters are located on the lateral side in three stories of 10 m wide and 1 1/4 m in length, and also, in smaller size, at the beginning of the shops.

In Fig.187, the plan of the general components in one building of the mechanical, assembly, diesel-engine, gas-generator, cold-stamping and chassis shops of a tractor works is represented.

The whole area of the body is 180,540 square meters, with a length of 540 and a width of 201 m, has twelve aisles, eight of which are 12 m wide, two of which are 21 m wide and two of which are 18 m wide, with a column spacing of 12 m. The shops include: diesel-engine (treatment and assembly), chassis (treatment and assembly), normal, heat-treating. At the beginning of each shop, a storage of blanks and materials is located.

For the enumerated shops, the conveyor of the assembly of trucks, the conveyor of the assembly of gear boxes, the main conveyor of the general assembly of tractors with painting chamber, are present.

On the other side of the main conveyor, the gas-generator and cold-stamping shops are present, and also the departments of polishing of tractors, finishing of gas generators, elimination of defects, outfitting and delivery of tractors.

On both sides of the body, over the whole length, in annexes, living quarters are located - southern (width of 9 m) and northern (width of 2 1/4 m).

Along the northern part of the body, over the whole length, there runs a wide-gauge railroad-track.

In Fig.188 (compare inlay at end of book), the plan of the general components in one building of the several shops of a tractor works is presented. In the building, the following shops are located: tractor, transmission, heat-treating, unit assembly, painting, general assembly, testing and a number of auxiliary departments. The office and living quarters are located in a second story. The total length of the body on one side is 210 and on the other 198 m; the width is 102.26 meters.